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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

1. This report presents detailed investigations undertaken to evaluate the potential effects of withdrawing ground water at a rate of approximately 725 acre-feet per year for a period of 10 years for a proposed open pit heap leach gold mine in northeastern San Bernardino County, California. A number of production and processing changes have been incorporated into the project in order to reduce earlier water use projections of 1,650 and 1,140 acre-feet per year, which were reported in prior reports (Viceroy 1988).

2. The proposed Castle Mountain Project would be located at the south limits of the Castle Mountains in the northeast portion of the approximately 340-square mile Lanfair Valley as shown in Figures 1.1 and 1.2. Lanfair Valley is a semi-enclosed basin, located at a higher elevation than surrounding valleys. The proposed primary source of the project water is wells drilled and completed into unconsolidated alluvium, located in an area centered approximately two miles west of the mining operation, known as the West Well Field. A small volume of the required water may also be obtained from wells completed in volcanic rock in the project area. This potential secondary area is known as the East Well Field.

3. Impacts from pumping for the anticipated 10-year operation period have been investigated more extensively than is typical for similar projects because of public concern regarding the potential for ground water removal to adversely affect flow conditions at Piute Spring, which is located approximately 16 miles south-southeast of the West Well Field. Piute Spring is an important environmental feature in this region because it is the largest source of perennial (year-round) stream flow. The spring supports approximately nine acres of riparian vegetation.

4. Piute Spring emerges in the Piute Gorge, an eroded canyon in the southern Piute Range. The spring flows easterly into the adjacent Piute Valley at the location shown in Figure 1.2. The elevation of the spring is about 80 feet lower than the measured ground water level in the adjacent portion of Lanfair Valley. Public concern has been expressed that because of this elevation difference and the location of the spring, all or a major portion of its source may be from the Lanfair Valley aquifer. Therefore, if pumping for the project were to significantly lower water table levels in Lanfair Valley, flow at Piute Spring might be significantly affected.

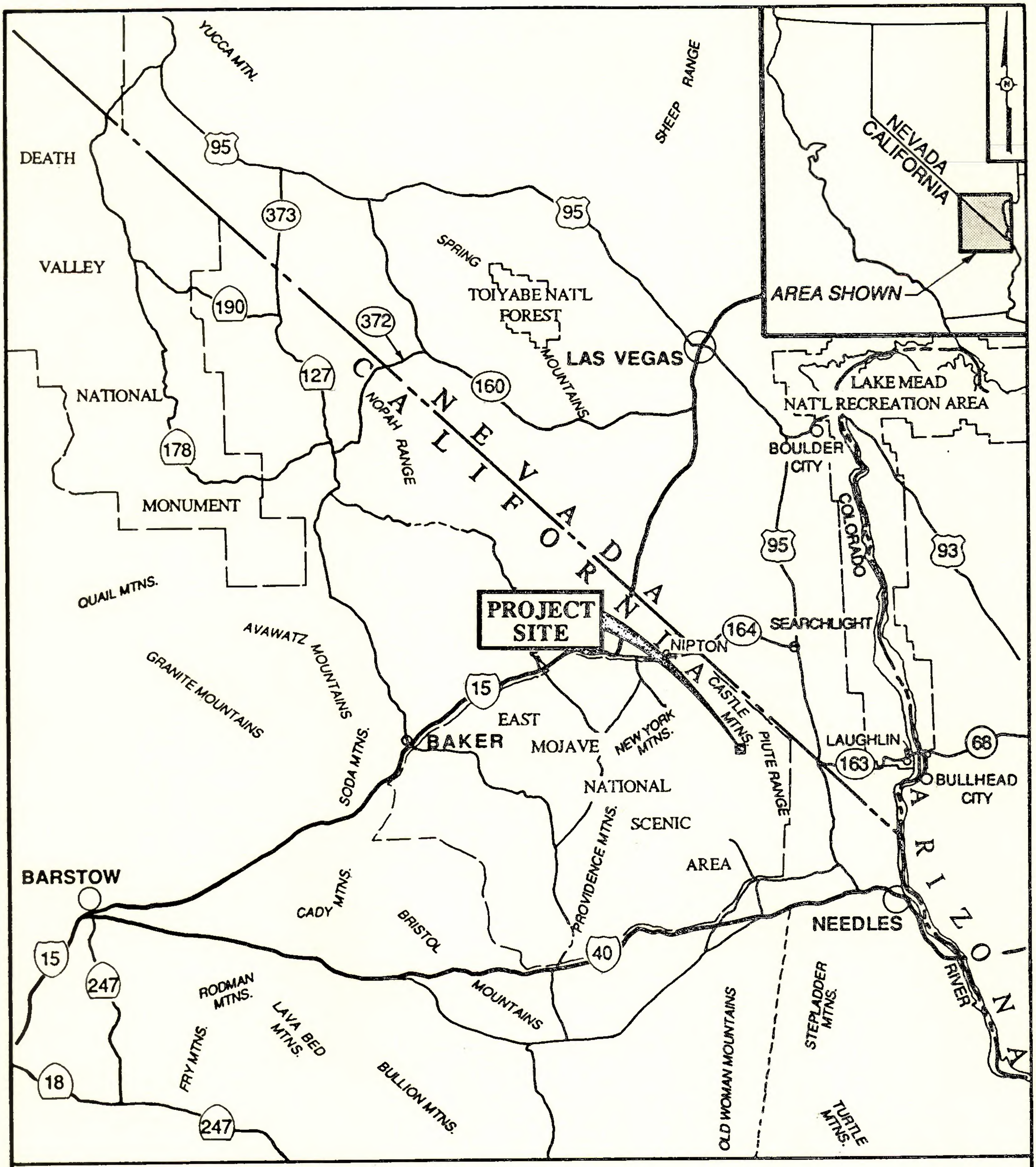

FIGURE 1.1

REGIONAL LOCATION MAP

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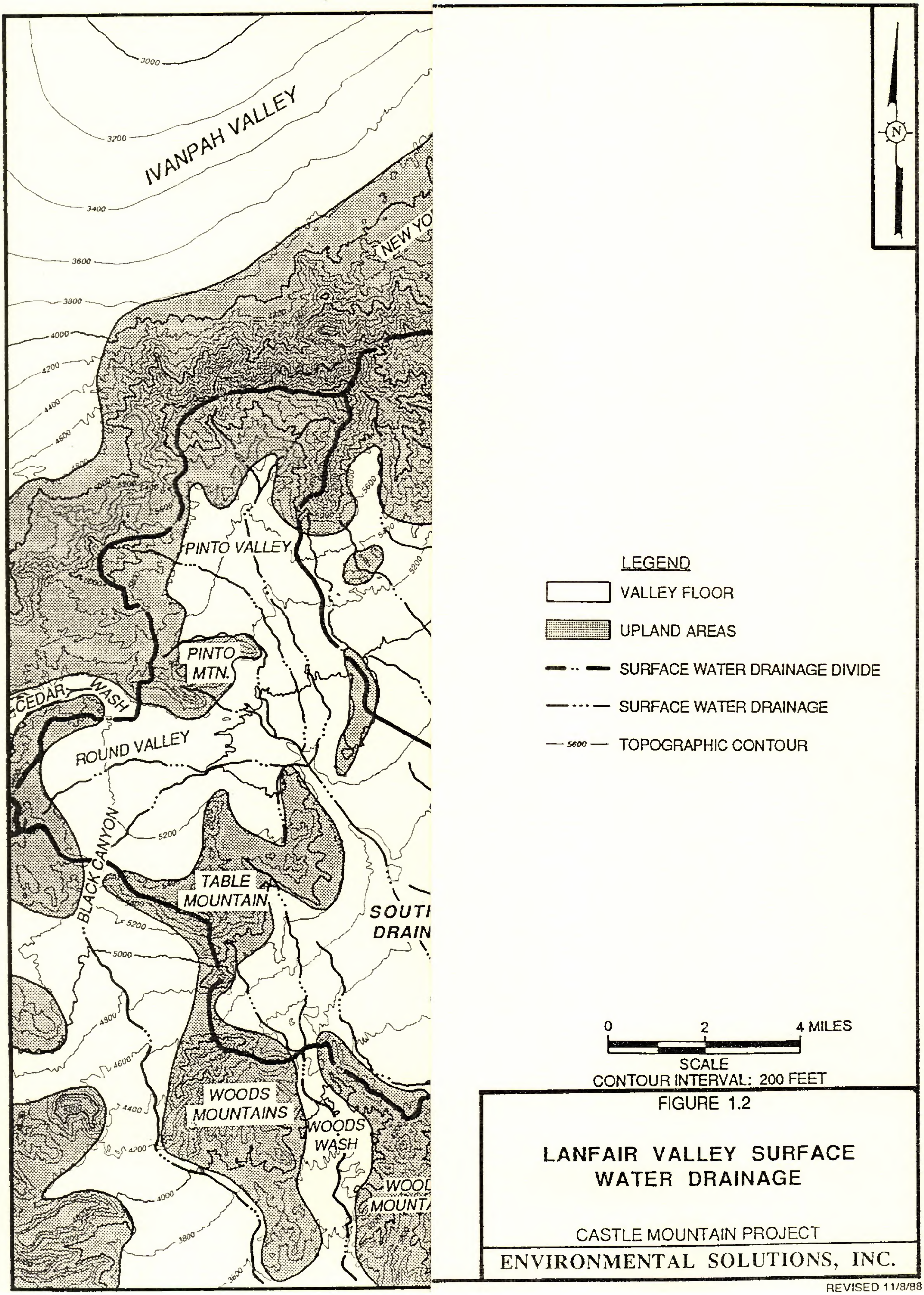

FIGURE 1.2

LANFAIR VALLEY SURFACE WATER DRAINAGE

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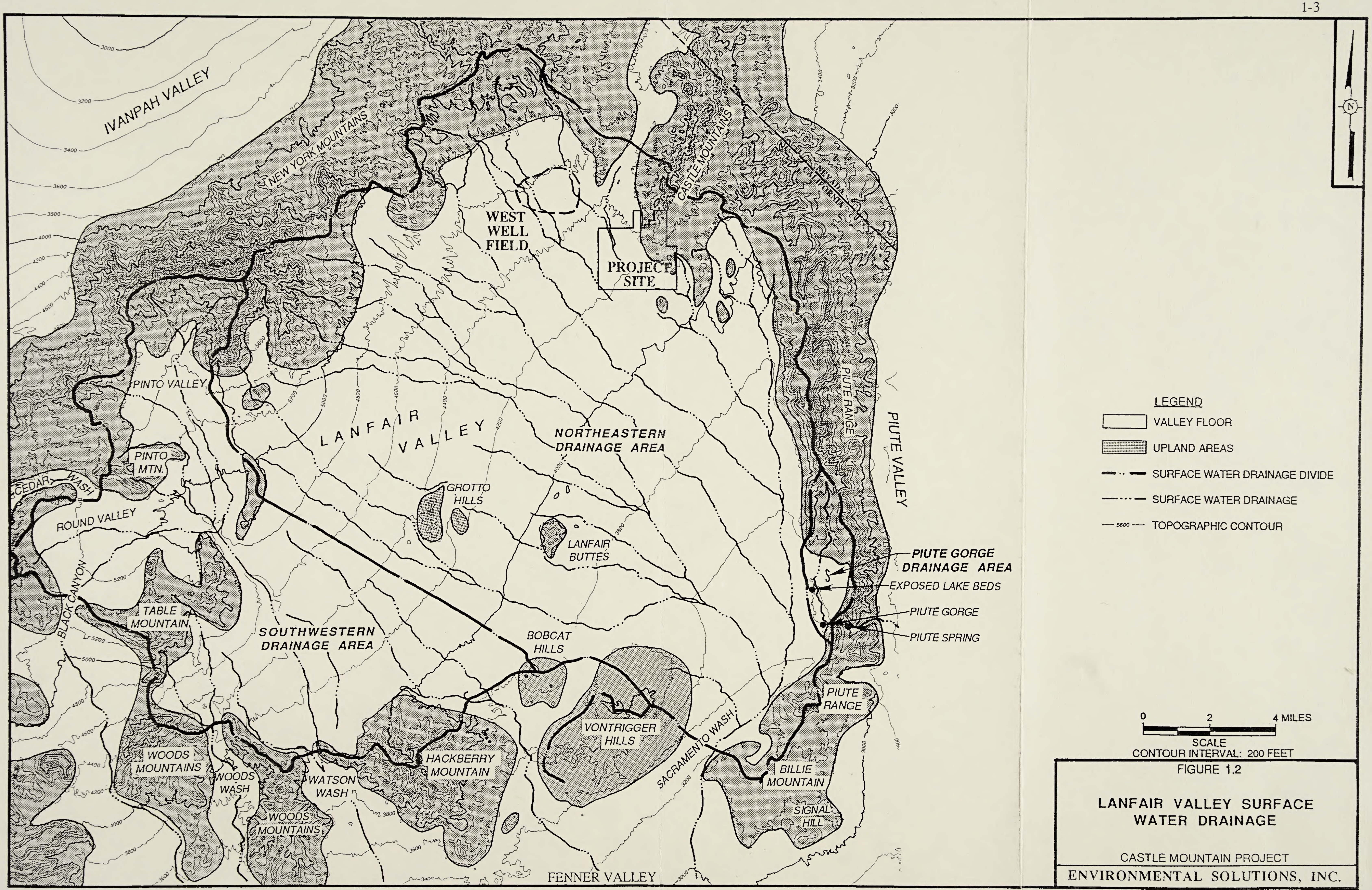

FIGURE 1.2

LANFAIR VALLEY SURFACE WATER DRAINAGE

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5. The public and agencies have also asked if there is potential for the proposed project pumping to affect smaller springs, generally located in the hills surrounding the Lanfair Valley, or the few existing private water supply wells in the area. Both of these conditions have been evaluated and are discussed in this report.

6. The methodology and results of investigations undertaken to address these areas of public concern are discussed in this report. The discussion is presented in the following chapters:

   - Chapter 2.0 summarizes available background data and current investigations used for this evaluation.
   - Chapter 3.0 describes the existing hydrogeologic environment for Lanfair Valley and Piute Spring. Factors include geology and hydrologic settings, hydraulic properties of soils and rock, water balance (recharge and discharge) conditions in the Valley, and existing water quality.
   - Chapter 4.0 describes water supply requirements for the proposed project.
   - Chapter 5.0 describes analyses completed to evaluate potential impacts of the proposed pumping. The calculations have considered the West Well Field area, and the entire Lanfair Valley, including smaller springs near the well field, and conditions in the vicinity of Piute Spring.

1.2 SUMMARY

1. It is probable that the primary source of water for Piute Spring flow is from ground water in the Lanfair Valley alluvium, flowing through the volcanic rocks which form the mountains of the Piute Range. A small portion of the spring flow may also be contributed from direct recharge into the Piute Range rocks. Flow at the spring represents only a portion of the total discharge which occurs as underflow from the elevated Lanfair Valley into the lower Piute Valley, along the entire length of the Piute Range. Most of this underflow is not evident because the water surface is usually below the ground surface. Surface discharge occurs at the Piute Spring area because this is the only location along the range where deep erosion into the rock and downgradient Piute Valley alluvium has occurred to the extent that the ground surface has actually intercepted the water table surface.

2. Flow in the rock occurs along fracture and fault zones associated with uplifting of the Piute Range. At most locations, the general flow direction is approximately perpendicular to the north-south axis of the range, in the direction of the topographic gradient which exists between the Lanfair and Piute Valleys (west to east). Near Piute Spring, some flow also

occurs in fractured and faulted zones along the axis of the range (north to south). This occurs because the eroded valley and spring flow have lowered the normal ground water level locally so that a gradient exists both perpendicular and parallel to the axis of the range.

3. Discharge to the spring area is most evident at the first location of water emittance. However, downstream flow measurements and geologic mapping of the entire spring area indicate that discharge is occurring at a number of locations for a distance of at least 4,000 feet downstream from the first point of emittance. Flow at the first point of emittance is relatively constant at about 40 gpm, year-round. Total flow in the 4,000-foot-long, spring discharge area is more than 100 gpm (160 acre-feet per year). The surface expression of flow along the length of the stream varies greatly, apparently on a seasonal basis, with highest flows occurring in the winter. The most probable explanation for the downstream flow variation is that much of the water is lost during the spring and summer periods to surface evaporation and to transpiration by the riparian vegetation.

4. Ground water underflow between the Lanfair and Piute Valleys (including the spring) occurs along many fractures and faulted zones in the Piute Range, and it is appropriate to estimate flow rates according to the Darcy Theory of flow through porous media, wherein the amount of flow is directly proportional to the difference in ground water elevation between the two valleys. It is concluded, therefore, that if the Lanfair Valley ground water level were to be lowered, the Piute Spring flow would be reduced approximately by the same percentage as the reduction in difference between valley ground water level and the spring.

5. The water balance of Lanfair Valley is dependent upon recharge from precipitation (6 to 12 inches per year, depending on elevation) and ground water discharge to adjacent valleys. It is believed that the elevated position of the Valley precludes any substantial ground water inflow from adjacent basins. A conservative estimate of precipitation infiltration recharge into the entire Lanfair Valley is 2,000 acre-feet per year. It is estimated that under long-term equilibrium conditions, approximately 850 acre-feet per year of this recharge is discharged as underflow to the adjacent Fenner Valley, primarily from the approximate 95-square mile, southwestern portion of the Lanfair Valley. Approximately 1,150 acre-feet of underflow is estimated to occur between the Lanfair and Piute Valleys through the Piute Range, in balance with estimated recharge to the 245-square mile northeastern portion of the Lanfair Valley. Approximately 200 to 250 acre-feet per year of this latter flow occurs at Piute Spring.

6. Calculated recharge to the West Well Field is estimated at 400 (300 to 500) acre-feet per year. At a withdrawal rate of 725 acre-feet annually, pumping the well field will cause localized ground water mining to occur at a rate of about 325 acre-feet per year. Modeling at the well field area by the Mark Group, Inc. (1988) (1) shows that an average drawdown of less than 60 feet is estimated to occur over the general area of the well field for the proposed amount of pumping. Local drawdown would be greater in the vicinity of each pumping well location. Changes in ground water level due to pumping are predicted to be less than 10 feet for distances generally greater than two miles from the well field area.

7. The calculated amount of ground water in storage in the 7-square mile area which would be subject to predicted water level declines of 10 feet or more is 112,000 acre-feet. Based on the estimated deficit of about 325 acre-feet per year, annual storage depletion in the affected area would be three percent for the planned 10-year period of pumping. The proposed pumping would not adversely affect existing private wells in Lanfair Valley, which, with the exception of well 27A1 (T.14N., R.17E.), are at least six miles from the West Well Field, and therefore are outside of the area of greatest drawdown. The several small springs located several miles to the north and west of the proposed well field are also outside of the area of drawdown and would not be affected.

8. The potential effects of the proposed water withdrawal at Piute Spring are evaluated in two ways. First, if it is assumed that the entire 7,250 acre-feet of ground water proposed to be pumped over a 10-year period would result in a uniform decrease in water level throughout the 245-square mile northeastern portion of the Lanfair Valley, a water level decrease of about 0.5 feet would occur upgradient from Piute Spring. This would cause a decrease of less than one percent of flow in the spring area, which would not be noticeable in relation to the existing natural seasonal variations.

9. The first analysis method could be unconservative, if the cone of depression near this well field were to migrate over time toward the spring area so that the drawdown then would be much larger than 0.5 feet. To account for this theoretical possibility, a second method of analysis was completed, using a computerized three-dimensional model analysis of the basin to predict the potential effect of the West Well Field cone of depression over a long period.

---

(1) See Appendix A for references.

The model projection was extended from the initiation of pumping, to 1,000 years after pumping would be stopped. The results indicate that direct drawdown effects of pumping would not noticeably move toward the spring area and that even the localized effects of pumping would essentially be eliminated by natural recharge within a 30-year period. The model predicts no change in spring flow for the 1,000-year period.

10. Based on the various evaluations and analyses discussed in this report, it is concluded that the proposed pumping from the West Well Field would have no noticeable adverse effect at Piute Spring, other smaller springs, or existing private wells in the area.

2.0 SOURCES OF DATA

2.1 PREVIOUS INVESTIGATIONS

1. The hydrology and ground water resources of the Lanfair and Fenner Valleys were investigated by David A. Freiwald (1984) of the U. S. Geologic Survey (USGS) to provide data for future water-resource planning and development. The study includes an evaluation of the suitability of the Valley's ground water resources as a water supply and provides comprehensive inventories of well, spring, and water chemistry data.

2. The California Division of Water Resources (1956) published a report on water well and ground water data for the arid desert regions of southeastern California to provide baseline information for future development. In 1921, David G. Thompson initially characterized the ground water in Lanfair Valley in a USGS Water Supply Paper. The bulk of these reports is also included in the work by Freiwald (1984).

3. A variety of additional investigations for the desert areas of California and Nevada have also been consulted. These references are included in the bibliography provided in Appendix A. When appropriate, reference to specific reports are made within the text of this study.

4. Figure 2.1 shows the location of well and spring data points in or adjacent to the Lanfair Valley. This figure shows data from these previous reports and more recent borings and wells, installed specifically for the proposed Castle Mountain project as discussed below.

2.2 INVESTIGATIONS UNDERTAKEN FOR THE PROPOSED PROJECT

1. In late 1986 and early 1987, Mifflin & Associates (1987) drilled three exploratory borings (L-1, L-2, and P-3 in Figure 2.1) into the Lanfair Valley alluvium at the request of the Applicant. The data are incorporated into interpretations of additional borings and wells installed by others, as discussed below.

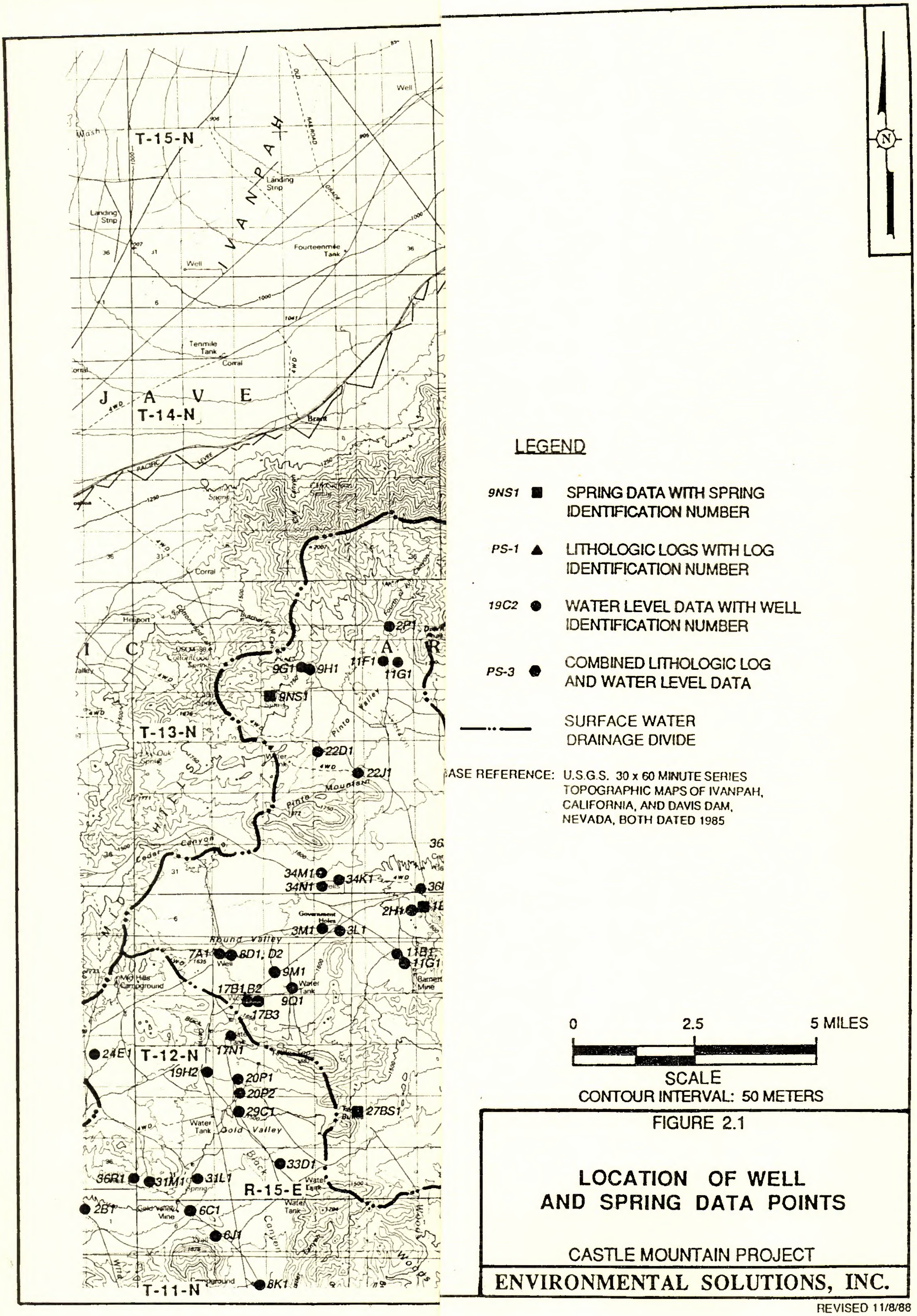

FIGURE 2.1

LOCATION OF WELL AND SPRING DATA POINTS

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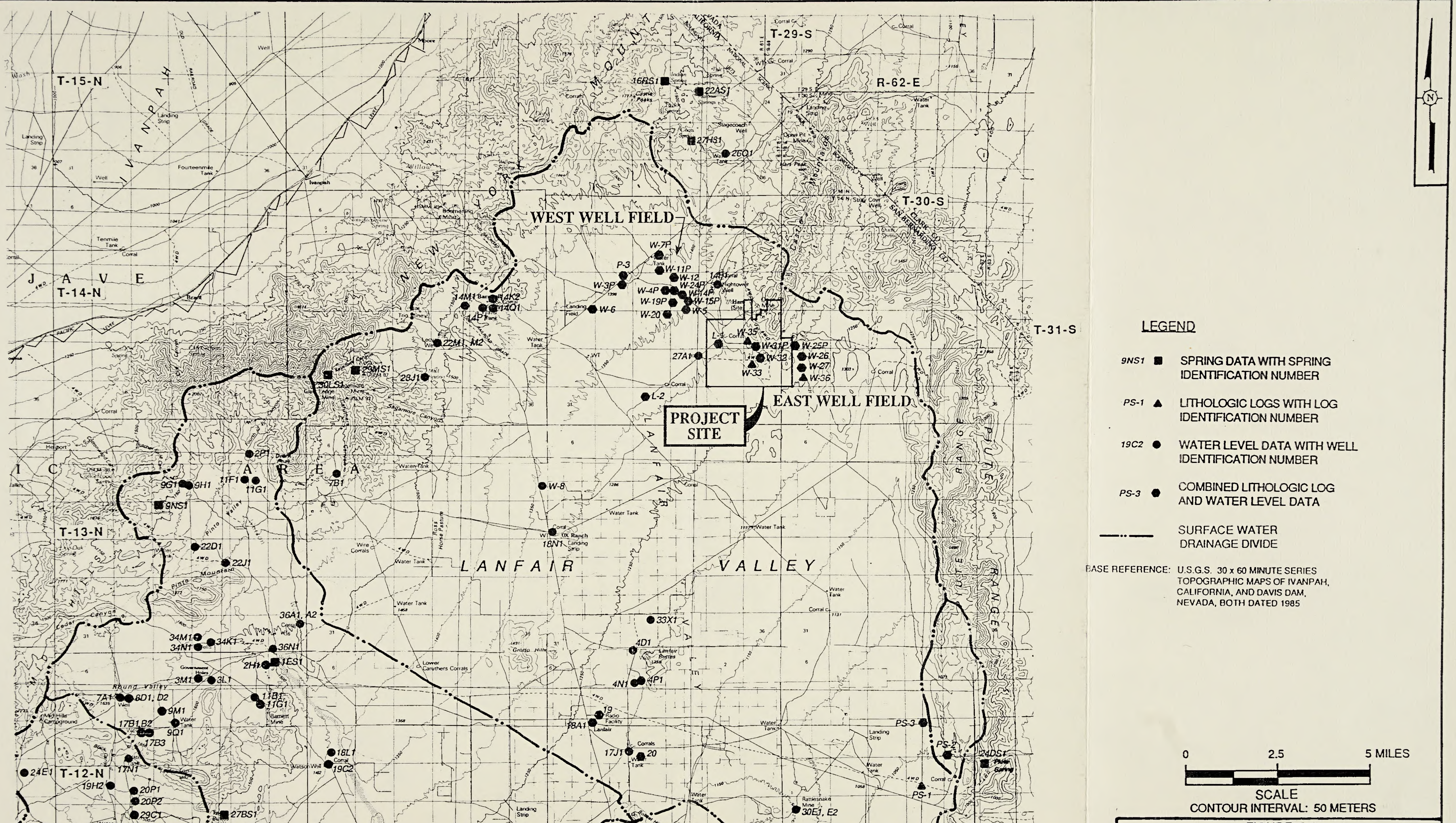

LEGEND

9NS1 ■	SPRING DATA WITH SPRING IDENTIFICATION NUMBER
PS-1 ▲	LITHOLOGIC LOGS WITH LOG IDENTIFICATION NUMBER
19C2 ●	WATER LEVEL DATA WITH WELL IDENTIFICATION NUMBER
PS-3 ⬢	COMBINED LITHOLOGIC LOG AND WATER LEVEL DATA
—··—	SURFACE WATER DRAINAGE DIVIDE

BASE REFERENCE: U.S.G.S. 30 x 60 MINUTE SERIES TOPOGRAPHIC MAPS OF IVANPAH, CALIFORNIA, AND DAVIS DAM, NEVADA, BOTH DATED 1985

0 2.5 5 MILES
SCALE
CONTOUR INTERVAL: 50 METERS

FIGURE 2.1

LOCATION OF WELL AND SPRING DATA POINTS

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2. The Mark Group, Inc. (1987, 1988) was retained by Viceroy Gold Corporation to conduct a variety of hydrologic studies related to development of a ground water supply for the proposed project. Their studies have included:

   - The drilling of 22 exploratory borings of which about 10 are proposed as production wells in the West and East Well Fields for the proposed project.
   - Conducting a Bouguer gravity survey in the vicinity of the West Well Field to provide an indication of alluvial thickness.
   - Detailed interpretation of geologic conditions in the well field areas.
   - Conducting aquifer pumping tests on each individual production well and a longer, 72-hour aquifer pumping test using three wells in the West Well Field.
   - Drilling of three borings and installation of one well in Lanfair Valley, upgradient from Piute Spring.
   - Surveying to determine the elevation of the well and one of the borings upgradient from Piute Spring, and the point of first emittance of the spring.
   - Monitoring of Piute Spring flows monthly since June 1987.
   - Preparation of water budget estimates for the West Well Field and the entire Lanfair Valley.
   - Detailed computer modeling of aquifer performance in the West Well Field.
   - Water quality reconnaissance for the area.
   - Preliminary analyses of the potential effects of pumping for the project on Piute Spring.

3. A variety of field and laboratory analyses activities have been conducted by Steffen Robertson and Kirsten (SRK, 1987) in the proposed project site area. This was a part of the investigations necessary to design containment systems for the proposed heap leach facilities, required to satisfy regulatory requirements of the California Regional Water Quality Control Board (RWQCB), Colorado River Basin.

4. Environmental Solutions, Inc. staff has also conducted a number of independent investigations to further characterize hydrogeologic conditions in the Lanfair Valley. These activities have included:

    - Detailed geologic mapping of the Piute Gorge.
    - Reconnaissance of the overall Lanfair Valley geologic conditions, and evaluation of the Valley's geology with respect to anticipated hydrogeologic performance.
    - Measuring of Piute Creek stream flows at several locations for a distance of 7,000 feet downstream from the first point of emittance.
    - Preparation of a potentiometric contour map for the entire Lanfair Valley.
    - Reconciliation of water balance conditions in the Valley, including consideration of probable discharge conditions at the Fenner Valley boundary, through the Piute Mountain range and at Piute Spring.
    - Determining estimates of flow rates and quantities across Lanfair Valley toward the Piute Range.
    - Running of a three-dimensional ground water model for the entire Lanfair Valley to evaluate effects of pumping during the proposed operation and for a period of 1,000 years after pumping to determine the potential for significant water level decreases in the vicinity of Piute Spring.
    - Evaluation of potential impacts of pumping on Piute Spring, other smaller springs closer to the West Well Field, and private wells in Lanfair Valley.

3.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

1. The existing conditions discussed in this section are directed specifically toward describing factors which must be considered to evaluate the potential environmental effects of ground water withdrawals from the West Well Field, and especially effects which might occur at Piute Spring. The descriptions are based on the data and analyses described in Chapter 2.0.

2. The existing environment is described in the following sections:

- Section 3.1 Climate
- Section 3.2 Geologic Setting
- Section 3.3 Hydrogeologic Setting
- Section 3.4 Hydrogeologic Properties
- Section 3.5 Water Balance
- Section 3.6 Water Quality

3.1 CLIMATE

1. The climate of Lanfair Valley is semi-arid with low precipitation, generally warm temperatures and high evapotranspiration. The amount of rainfall is highest in the mountain areas and decreases with decreasing elevation. The closest meteorological station with precipitation data is located in Searchlight, Nevada, approximately 16 miles northeast of the proposed Castle Mountain project site. Searchlight is at an elevation of 3,540 feet above sea level and receives a mean annual precipitation of 7.27 inches (Ruffner, 1985). The project site varies in elevation from about 4,100 to 4,600 feet.

2. French (1988, in progress) and Rush and Huxel (1966) have derived the relationships between known precipitation values and elevations in arid environments, shown in Figure 3.1. Applying these relationships to Lanfair Valley, it is estimated that average annual precipitation ranges from about six inches at the lowest elevation (3,200 feet) in the southeast corner of the Valley to more than 12 inches at the highest elevations (7,300 feet) in the New York Mountains.

3. Winter is the wettest season, including occasional snow at higher elevations. Based on Searchlight data, as much as 65 percent of the precipitation occurs between mid-September and mid-April and approximately 25 percent of the precipitation occurs as late summer (July and August) thunderstorms. Spring (May and June) is normally the driest period of the year with about 10 percent of annual rainfall.

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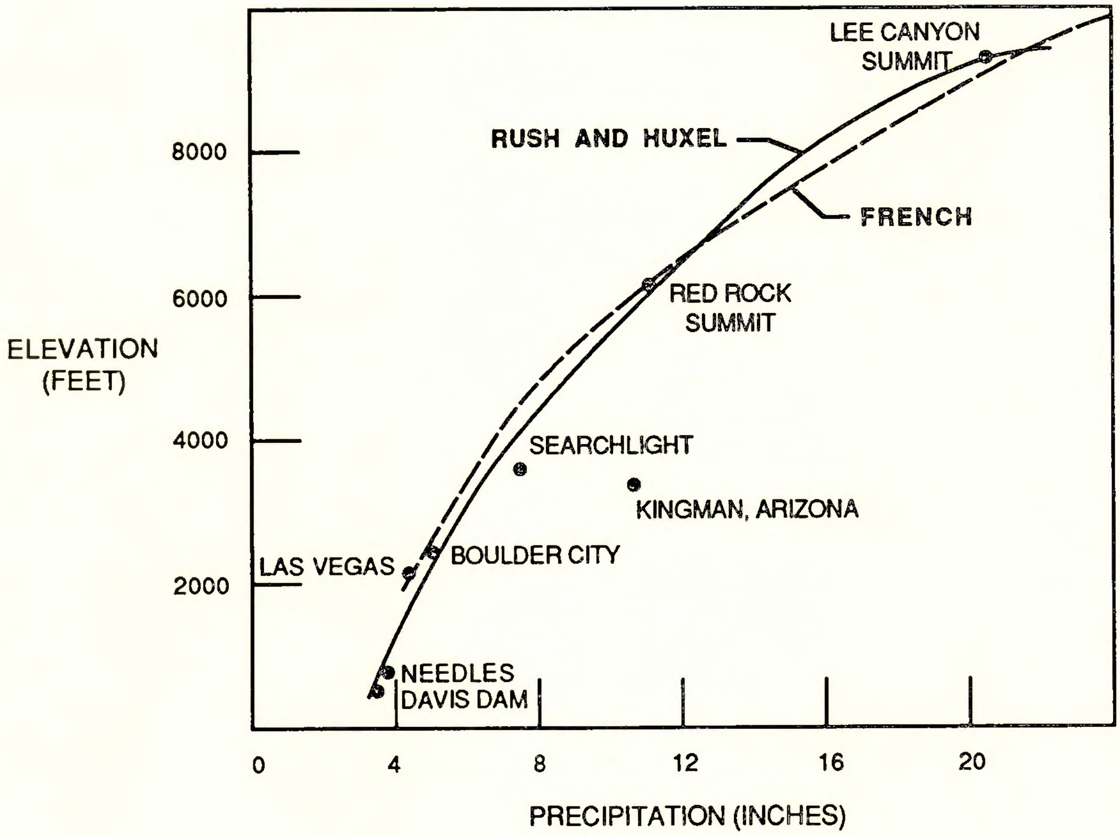

RELATIONSHIP OF ELEVATION TO AVERAGE ANNUAL PRECIPITATION

SOURCE: RUSH AND HUXEL, 1966
FRENCH, IN PROGRESS

FIGURE 3.1

RELATIONSHIP OF PRECIPITATION TO ELEVATION

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4. Mean temperatures reported for Searchlight for the 1951 to 1980 period (Ruffner, 1985) are:

	Temperature in °F Daily Maximum	Daily Minimum	Monthly
January	53.3	34.8	44.1
February	58.7	37.6	48.2
March	64.0	40.2	52.1
April	72.5	46.8	59.7
May	81.9	55.0	68.5
June	92.4	64.6	78.5
July	97.9	71.5	84.7
August	95.3	69.7	82.5
September	89.3	63.4	76.4
October	77.7	54.1	65.9
November	63.1	42.8	52.7
December	54.5	36.0	45.3
Year (Average)	75.1	51.3	63.2

5. Temperature extremes ranged from 8 to 109 degrees Fahrenheit. Winter temperatures in most of Lanfair Valley are assumed to be somewhat lower than Searchlight's due to the higher elevations, while summer temperatures are anticipated to be similar.

3.2 GEOLOGIC SETTING

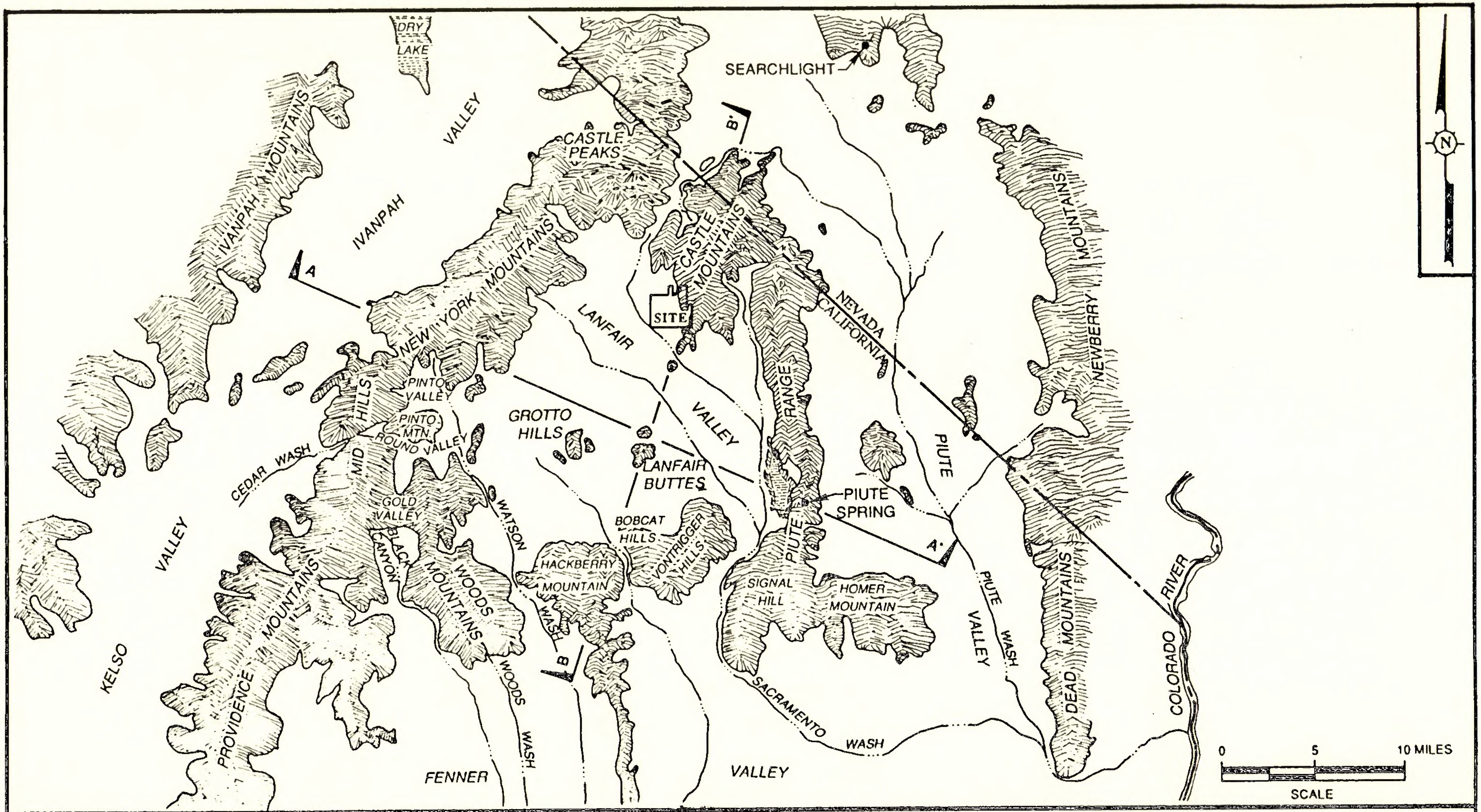
1. The following discussion of geology is directed specifically toward describing geologic factors which may influence hydrogeologic conditions in Lanfair Valley and/or at Piute Spring. The discussion considers the following locations:

- Section 3.2.1 General Lanfair Valley Geology.
- Section 3.2.2 Proposed Well Field Geology.
- Section 3.2.3 Water Gap Geology.
- Section 3.2.4 Piute Gorge Geology.

The hydrogeologic setting is described in Section 3.3.

3.2.1 GENERAL LANFAIR VALLEY GEOLOGY

1. Lanfair Valley (Figures 3.2, 3.3, and 3.4) encompasses approximately 340 square miles of surface watershed area. Approximately 260 square miles of alluvial fill (basin floor) exist within the basin, surrounded by igneous and metamorphic bedrock uplands.



LEGEND

A A' CROSS-SECTIONS

—··· — MAJOR SURFACE DRAINAGES

NOTE: SEE FGURE 3.3 FOR
CROSS-SECTIONS.

FIGURE 3.2

REGIONAL PHYSIOGRAPHY

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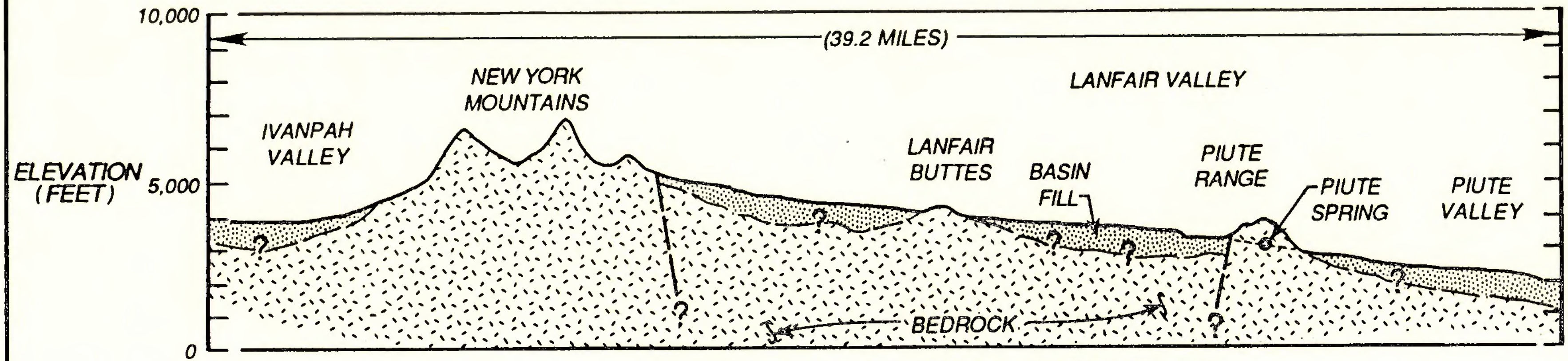
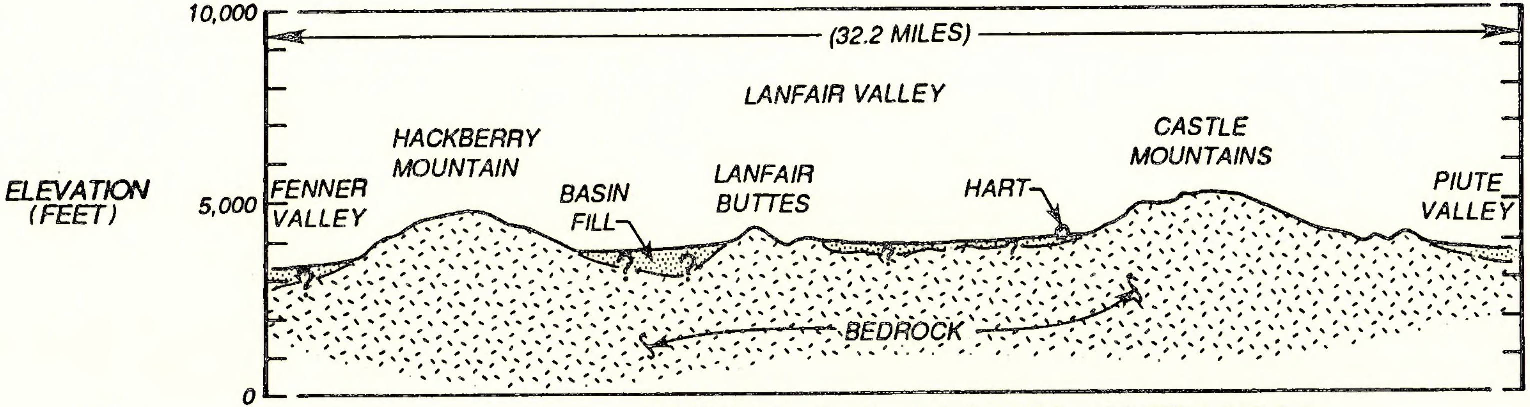


SECTION A-A', LOOKING NORTHEAST



SECTION B-B', LOOKING NORTHWEST

HORIZONTAL SCALE: 1 INCH = 5 MILES

VERTICAL SCALE: 1 INCH = 5,000 FEET

FIGURE 3.3

LANFAIR VALLEY GEOLOGIC CROSS-SECTIONS

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NOTE: SEE FIGURE 3.2 FOR
CROSS-SECTION LOCATIONS.

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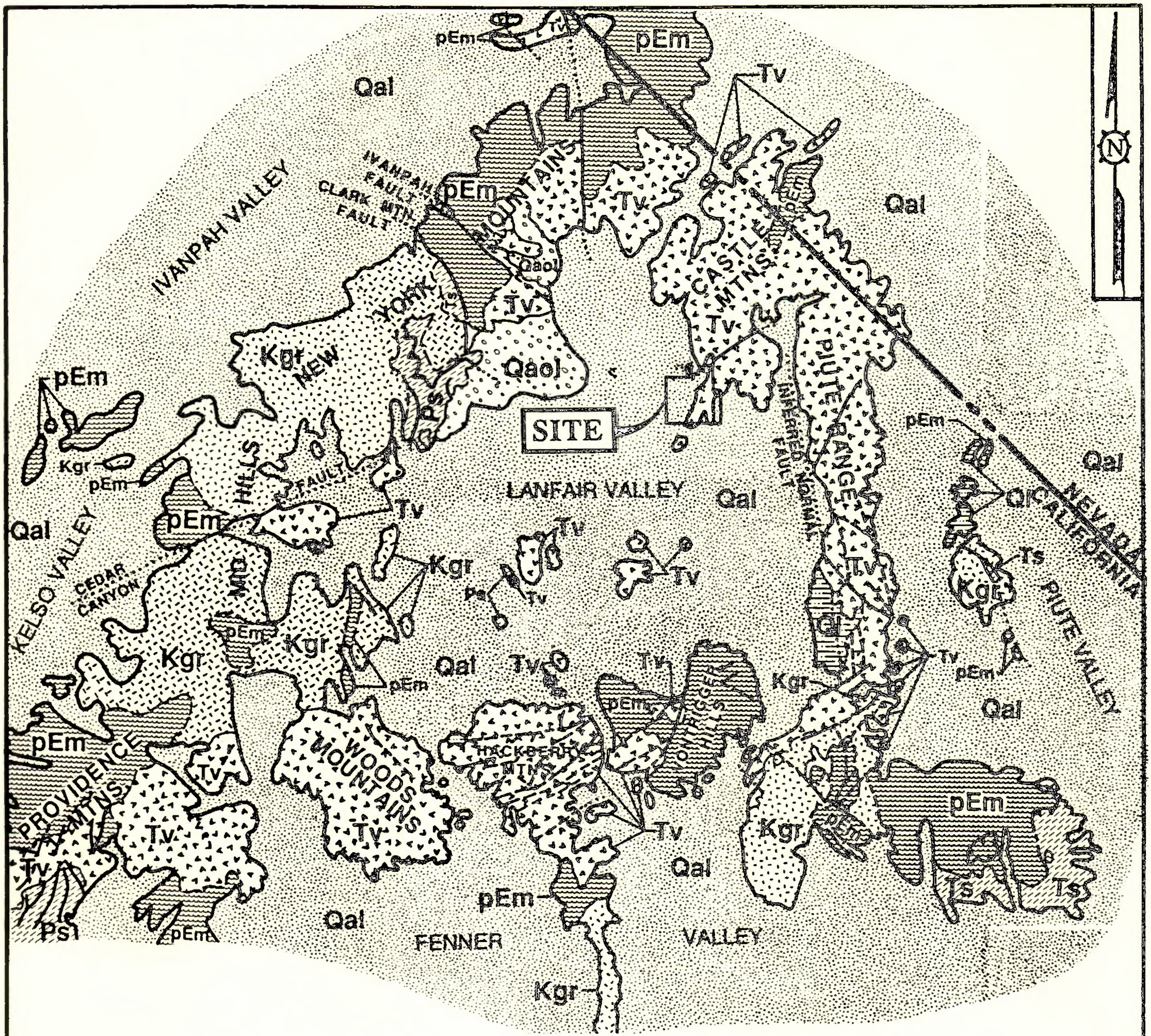

EXPLANATION:

(Qal)	RECENT BASIN ALLUVIUM
(Qaol)	PLEISTOCENE BASIN ALLUVIUM
(Ql)	PLEISTOCENE LACUSTRINE DEPOSITS
(Ps/Ts)	PALEOZOIC/TERTIARY SEDIMENTARY ROCKS
(Qv/Tv)	QUATERNARY/TERTIARY EXTRUSIVE VOLCANICS
(Kgr)	CRETACEOUS INTRUSIVE GRANITICS
(pEm)	PRECAMBRIAN METAMORPHIC/GRANITIC BASEMENT

FAULTS, DASHED WHERE APPROXIMATE, DOTTED WHERE CONCEALED. BARB (Δ) INDICATES A THRUST FAULT.

0 5 10 MILES
SCALE

REFERENCE: MODIFIED AFTER JENNINGS 1961 AND 1966
AND LONGWELL ET AL. 1965

FIGURE 3.4

REGIONAL GEOLOGIC MAP

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2. The basin floor is approximately 20 miles wide at the longest point from east to west and 17 miles at the longest point from north to south. Elevations of the basin floor (excluding uplands) range from 3,200 feet at its southeastern extreme near the Vontrigger Hills, to over 5,000 feet at the northern limits adjacent to the New York Mountains, and over 5,600 feet in the western portion near Pinto Valley. The bedrock upland portions of the basin comprise an area of approximately 80 square miles and vary in elevation from 3,300 feet at the southern end of the Piute Range to about 7,300 feet in the New York Mountains.

3. The basin floor displays relatively low relief with gradients of 50 to 200 feet per mile. Gradients increase rapidly around the basin margins and on the upper portion of the alluvial fans adjacent to the uplands. Stream incision also increases at the basin margins.

4. Streams within the basin are ephemeral, flowing only for brief periods in direct response to precipitation. The Valley contains the three surface water subbasins, shown in Figure 1.2. The Southwestern watershed covers an area of approximately 95 square miles and drains toward the south through one of five water gaps: (1) Cedar Wash, (2) Black Canyon, (3) Woods Wash, (4) Watson Wash, and (5) the unnamed gap between Hackberry Mountain and Vontrigger Hills. These gaps each flow into Fenner Valley to the south, except Cedar Wash, which flows into Kelso Valley to the west.

5. The Northeastern watershed covers an area of approximately 240 square miles. Surface water in the Northeastern watershed flows in several unnamed washes that trend to the southeast and join at the southeast corner of Lanfair Valley to form Sacramento Wash which turns south to southwest as it flows between Vontrigger Hills and the Piute Range into Fenner Valley. The third surface water subbasin is a 5-square mile watershed area which exists adjacent to the south end of the Piute Range and drains into a canyon incised into the Lanfair Valley and then into Piute Gorge, which is a rock canyon eroded into the Piute Range. The Piute Gorge area is important to this study because it contains Piute Spring, the largest naturally occurring perennial (year round) source of flowing water in the area.

6. Topographically, Lanfair Valley lies above the surrounding desert valleys in all directions. The elevation difference is usually abrupt on opposite sides of the dividing bedrock uplands, except at several water gaps where Lanfair Valley merges with Fenner Valley to the south. This elevated nature of the Valley is the result of alluvial backfilling within the enclosed upland bedrock area.

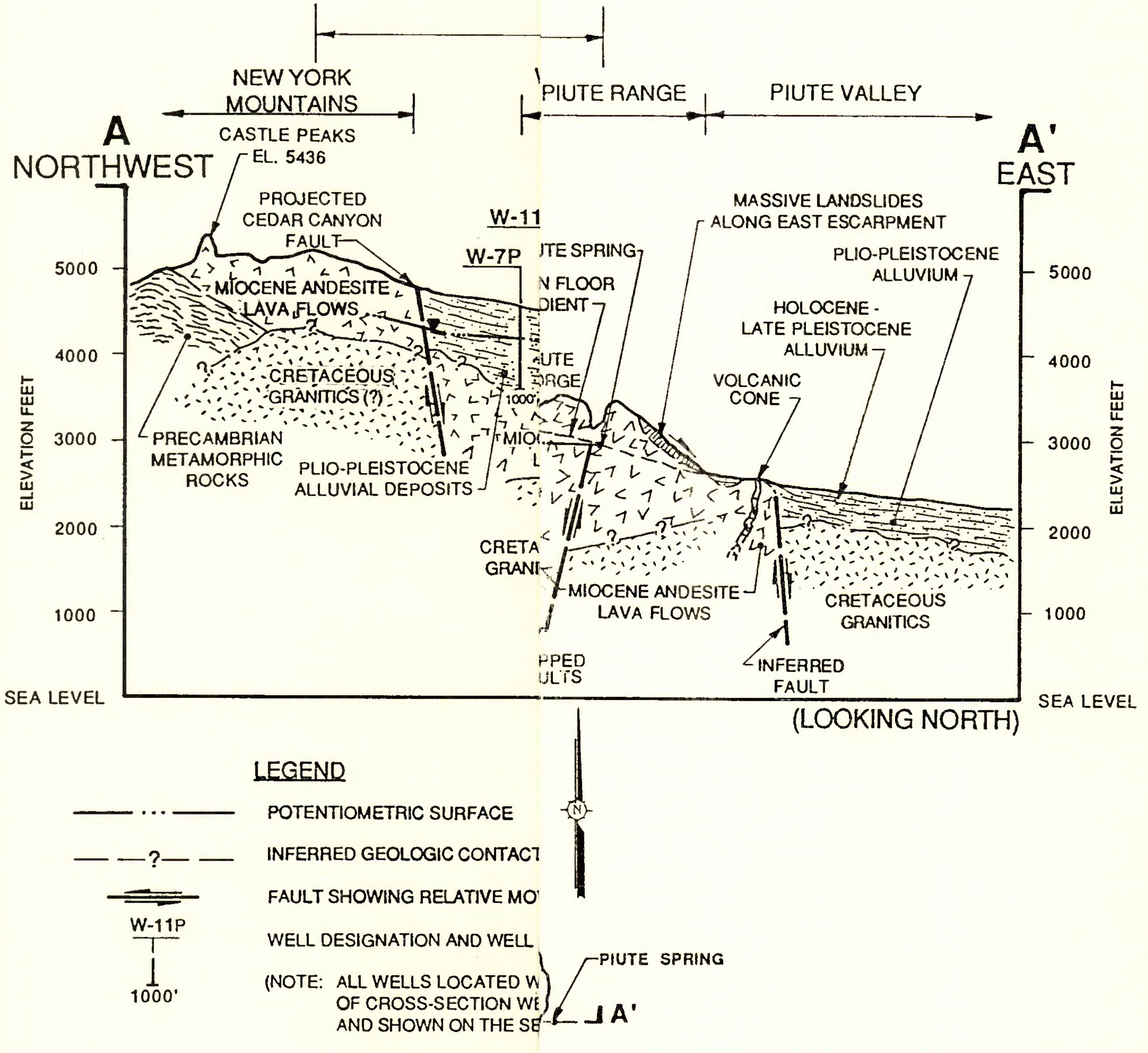
7. Figure 3.4 shows the geologic map for the Lanfair Valley region. Figure 3.5 shows a cross-section across the Valley from the proposed West Well Field to the Piute Spring areas. These figures are used to illustrate geologic conditions which are discussed in the following paragraphs.

8. The equidimensional shape of Lanfair Valley is somewhat unique as compared with other desert valleys in this region. Most basins are elongated in a north-south direction as a result of the regional basin and range tectonic patterns. This difference may occur because one north-south trending zone of higher bedrock is lower than the others and, therefore, is buried beneath the present alluvial surface. Based on the available geologic data, such a basin divide may occur along the discontinuously exposed ridge that trends to the northeast from Hackberry Mountain to the Castle Mountains (Figure 3.3 and Note 1 in Figure 3.5). Based on projection and composition of the aligned bedrock outcrops (inselbergs), such a buried ridge would most likely be composed of Miocene age volcanic extrusive rock types.

9. Basin bounding normal faults exist along the west side of the Piute Range and southwestern side of the New York Mountains. Similar extensional faults most likely trend along portions of the other uplands adjacent to the basin and now lie buried beneath alluvial deposits. Numerous faults with various trends have been mapped in the uplands around the Valley. Most of these appear to be normal faults, which accompanied the evolution of the basin and range province in late Tertiary and Quaternary time.

10. Regional Bouguer gravity (Oliver, et al., 1980) and aeromagnetic (Youngs, 1987) maps do not show distinct structural features within the basin. The gravity map indicates a low-relief constant gradient to the northwest into Ivanpah Valley and in a subdued way suggests a local increase in gradient from north to south across Lanfair Valley. The aeromagnetic map shows a strong magnetic anomaly within the basin immediately east of Lanfair Buttes. The signature and intensity of the magnetic anomaly within the basin is similar to those found in the Cima volcanic field approximately 30 miles to the west. Based on water well data (i.e., logs) and surface exposures, the most probable explanation for the anomaly is that Quaternary age basalt flows occur within the valley fill section of the basin.

11. Except near the perimeter of the Valley, borings and wells have not penetrated through the alluvium to underlying bedrock. Therefore, the alluvial thickness in the basin fill is not known. Several holes in the well fields have penetrated volcanics at various depths, several



NOTE 1: THE POSSIBLE SHALLOW BEDROCK Z
WHICH WOULD TEND TO ISOLATE THE
THE PIUTE SPRING, IS INTENTIONALLY
ASSUMPTION OF CONTINUOUS ALLUV
VALLEY IS CONSERVATIVE FOR ESTI
OF THE PUMPING.

FIGURE 3.5

LANFAIR VALLEY HYDROGEOLOGIC CROSS-SECTION

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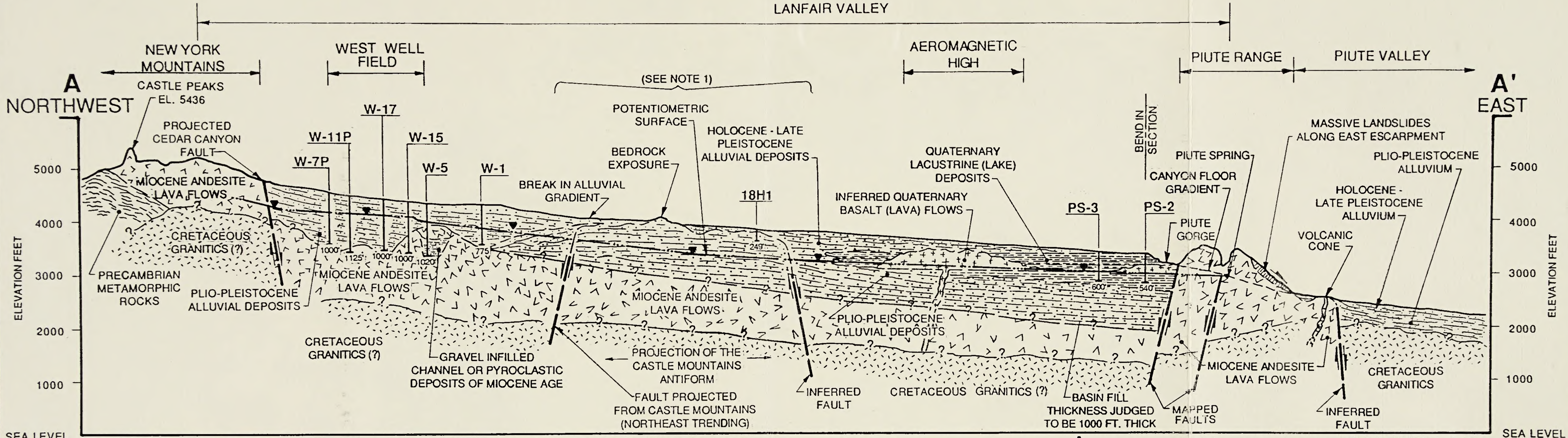

LANFAIR VALLEY
NEW YORK MOUNTAINS
WEST WELL FIELD
AEROMAGNETIC HIGH
PIUTE RANGE
PIUTE VALLEY
A
NORTHWEST
A'
EAST
(SEE NOTE 1)
CASTLE PEAKS
EL. 5436
PROJECTED CEDAR CANYON FAULT
MIOCENE ANDESITE LAVA FLOWS
CRETACEOUS GRANITICS (?)
PRECAMBRIAN METAMORPHIC ROCKS
PLIO-PLEISTOCENE ALLUVIAL DEPOSITS
W-17
W-11P
W-15
W-7P
W-5
W-1
1000'
1125'
1000'
1000'
1020'
775'
MIOCENE ANDESITE LAVA FLOWS
CRETACEOUS GRANITICS (?)
GRAVEL INFILLED CHANNEL OR PYROCLASTIC DEPOSITS OF MIOCENE AGE
BREAK IN ALLUVIAL GRADIENT
BEDROCK EXPOSURE
POTENTIOMETRIC SURFACE
HOLOCENE - LATE PLEISTOCENE ALLUVIAL DEPOSITS
18H1
249'
MIOCENE ANDESITE LAVA FLOWS
PROJECTION OF THE CASTLE MOUNTAINS ANTIFORM
FAULT PROJECTED FROM CASTLE MOUNTAINS (NORTHEAST TRENDING)
INFERRED FAULT
QUATERNARY LACUSTRINE (LAKE) DEPOSITS
INFERRED QUATERNARY BASALT (LAVA) FLOWS
PLIO-PLEISTOCENE ALLUVIAL DEPOSITS
CRETACEOUS GRANITICS (?)
PS-3
600'
PS-2
540'
BASIN FILL THICKNESS JUDGED TO BE 1000 FT. THICK
BEND IN SECTION
CANYON FLOOR GRADIENT
PIUTE SPRING
PIUTE GORGE
MAPPED FAULTS
MASSIVE LANDSLIDES ALONG EAST ESCARPMENT
PLIO-PLEISTOCENE ALLUVIUM
HOLOCENE - LATE PLEISTOCENE ALLUVIUM
VOLCANIC CONE
MIOCENE ANDESITE LAVA FLOWS
CRETACEOUS GRANITICS
INFERRED FAULT
ELEVATION FEET
5000
4000
3000
2000
1000
SEA LEVEL
(LOOKING NORTHEAST)
(LOOKING NORTH)

SECTION A-A'

LEGEND

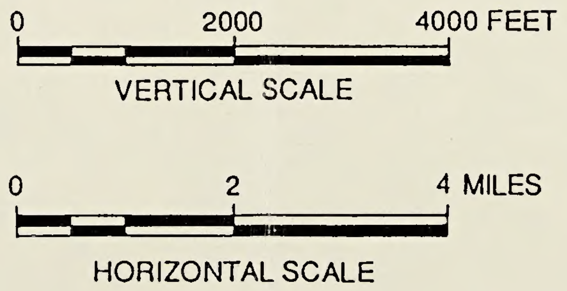
———···——— POTENTIOMETRIC SURFACE

— —?— — INFERRED GEOLOGIC CONTACTS

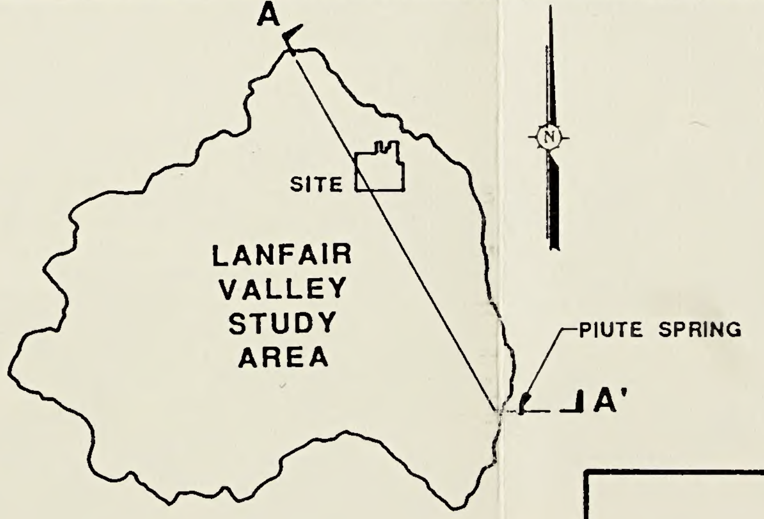
⇌ FAULT SHOWING RELATIVE MOVEMENT

W-11P 1000' WELL DESIGNATION AND WELL DEPTH

(NOTE: ALL WELLS LOCATED WITHIN 3000 FEET OF CROSS-SECTION WERE PROJECTED AND SHOWN ON THE SECTION.)



APPROXIMATE VERTICAL EXAGGERATION: 5:1



CROSS-SECTION LOCATION

NOTE 1: THE POSSIBLE SHALLOW BEDROCK ZONE IN THIS AREA, WHICH WOULD TEND TO ISOLATE THE WEST WELL FIELD FROM THE PIUTE SPRING, IS INTENTIONALLY NOT SHOWN. THE ASSUMPTION OF CONTINUOUS ALLUVIUM THROUGHOUT THE VALLEY IS CONSERVATIVE FOR ESTIMATING POTENTIAL IMPACTS OF THE PUMPING.

FIGURE 3.5

LANFAIR VALLEY HYDROGEOLOGIC CROSS-SECTION

CASTLE MOUNTAIN PROJECT

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others have penetrated alluvium only, and others have penetrated repeating sequences of alluvium and volcanics. Most likely, additional basin fill (i.e., older alluvium) underlies the volcanics and/or is interbedded with the volcanics.

12. The basin fill consists of at least four identifiable units, plus the surficial soil mantle. Bedrock underlying the basin fill is judged to be composed of mostly Miocene age volcanic rock types. The unconsolidated deposits are described from oldest to youngest as follows:

    - Ancient Alluvium (Plio-Pleistocene Age) - Exposed on the upper incised portions of fans especially at the north end of the basin and at a depth of a few tens of feet near the basin center(s). The unit consists of thick beds and lenses of sand-gravel combination with varying amounts of silt and clay. These detrital debris range from loose and unconsolidated to slightly indurated and moderately weathered. The ancient alluvium was derived from eroded sediments transported by high energy streams from the surrounding uplands and deposited on the basin floor in the form of fanglomerates.

    - Recent Alluvium (Late Pleistocene-Holocene Age) - Generally, unconsolidated alluvial debris have accumulated over most of the central basin area. These materials were derived from the surrounding uplands and degraded portions of the older fanglomerates. Deposition was mostly by fluvial (stream) action and to a minor degree eolian (wind) processes. Unconsolidated alluvium was deposited on broad outwash plains or on floors of incised drainages in bedrock and ancient fan terrains. The debris tends to become finer grained downgradient and consist of mostly sand and silt combinations with minor gravel fractions. Within 50 feet of the surface, calcium carbonate has accumulated in discontinuous beds and lenses to form cemented layers known as caliche.

    - Lacustrine (Lake) Deposits (Pleistocene Age) - A thick sequence in excess of 600 feet of horizontally lying lacustrine (lake) beds are exposed at the southwest end of the Piute Range and within the incised canyon upstream of the Piute Gorge. These deposits probably accumulated as a result of uplift and subsequent daming of the Piute Range. The lake deposits consist of dominantly unconsolidated sandy, silty, and gravely clay beds that range from thinly laminated to thickly bedded. The beds appear to be slightly tuffaceous and do not contain saline evaporates. Surface water in the lake was probably being decanted and possibly may have drained into an ancestral Piute Gorge. This process may have been the source of water which caused erosion of the bottom portion of the gorge and the upstream, incised canyon. It is expected that the lacustrine deposits are underlain by Ancient Alluvium which was deposited above the bedrock before the Piute Range was uplifted to form a lake condition in this basin.

    - Surface Soils (Late Pleistocene-Holocene Age) - Pedogenic soils generally developed during interglacial stages of geomorphic stability similar to the present. Desert soils (aridsols) require tens of thousands of years to develop due to lack of vegetation, high evaporation, low rainfall, and unstable geomorphic surfaces. Soil development in the Lanfair Basin is not apparent with regards to the evolution of a cambic horizon. The only evidence of soil development is the alluviated carbonates which have formed weak and thin to very strong and thick caliche layers. The soil deposits in the basin are generally a few inches or a few feet thick and consist of mostly sand that varies from silty to gravely. These deposits are somewhat excessively drained and have a relatively high hydraulic conductivity.

13. Figure 3.4 illustrates the types of rock which make up the hills and mountains surrounding the alluvial basin. The Castle Mountains and Piute Range represent the most important areas of bedrock for purposes of understanding hydrogeologic conditions necessary for this study. Both of these areas contain extrusive volcanics. These rocks are similar except the volcanics in the Piute Range appear to have more intense fracturing because uplifting of those mountains occurred more recently and the Castle Mountains are more weathered because of hydrothermal alteration.

3.2.2 GEOLOGY OF PROPOSED WELL FIELD

1. The East Well Field is located at the south end of the Castle Mountains in proximity to the project site and adjacent to the alluviated basin floor. Eight wells, drilled in the east field to depths up to 1,055 feet, have encountered volcanic bedrock at various depths below alluvial fill. Several wells penetrated interbedded unconsolidated sediments of sand, silt, gravel, and clay mixtures. Continuity of lithologic units among wells is not apparent, suggesting diverse depositional processes, irregular buried bedrock relief and/or possible structural discontinuities (i.e., faults). The East Well Field is not considered to be a reliable ground water source (Mark Group, 1988).

2. The West Well Field is located in the north-central portion of the alluviated basin about three miles southwest of the New York Mountain front and two miles west of the proposed project site. This area is characterized as an ancient alluvial fan surface that has been subjected to dissection by southeast flowing ephemeral streams. The local relief is relatively low and well rounded, and stream channels range from a few feet to several tens of feet in width. The numerous stream channels are mantled with a thin recent alluvium layer. The closest exposure of bedrock to the well field is an outcrop of Miocene age volcanic bedrock in the northeast corner of Section 15.

3. Fifteen borings spaced from a few hundred to a few thousand feet apart, have been drilled in the West Well Field to a maximum depth of 1,125 feet. Lithologies logged in the wells

indicate significant geologic differences over short distances, but generally show subsurface conditions to consist of mixtures of sand and gravel with varying amounts of silt and clay interbedded with an extensive body of volcanic rock at some locations. The volcanic rock is considered to be of low permeability and will not usually yield substantial quantities of water. The lithologic data for the unconsolidated materials do not indicate the presence of any regionally extensive confining layer within the alluvial materials. However, the lenticular characteristic of the alluvium could create semi-confined conditions for small areas.

3.2.3 WATER GAP GEOLOGY

1. Based upon published lithologic data, review of air photos and field reconnaissance, six surface water gaps (Figure 1.2) have been identified which could also represent potential ground water discharge zones in unconsolidated alluvial material. The water gaps are:

    - Cedar Wash
    - Black Canyon
    - Woods Wash
    - Watson Wash
    - Unnamed wash between Hackberry Mountain and Vontrigger Hills
    - Sacramento Wash

    These are generally alluviated channels ranging from 300 and 2,700 feet wide, between low- to moderate-relief bedrock exposures.

2. The alluvial thickness at the water gaps is unknown. However, this thickness can be estimated by projecting bedrock gradients below the alluvial cover. The largest, and most likely the deepest, Sacramento Wash, lies between the south end of the Piute Range and Vontrigger Hills. The alluviated section at this location has a minimum width between rock exposures of 2,700 feet (after mapping by Kohler, 1984). The buried bedrock surface is estimated to be at least 400 feet below ground surface (elevation 2,850 feet).

3. These alluvium filled water gaps may represent subsurface flow paths for a significant portion of ground water discharge between the Lanfair and Fenner Valleys. This discharge potential is discussed further in Section 3.5.3.

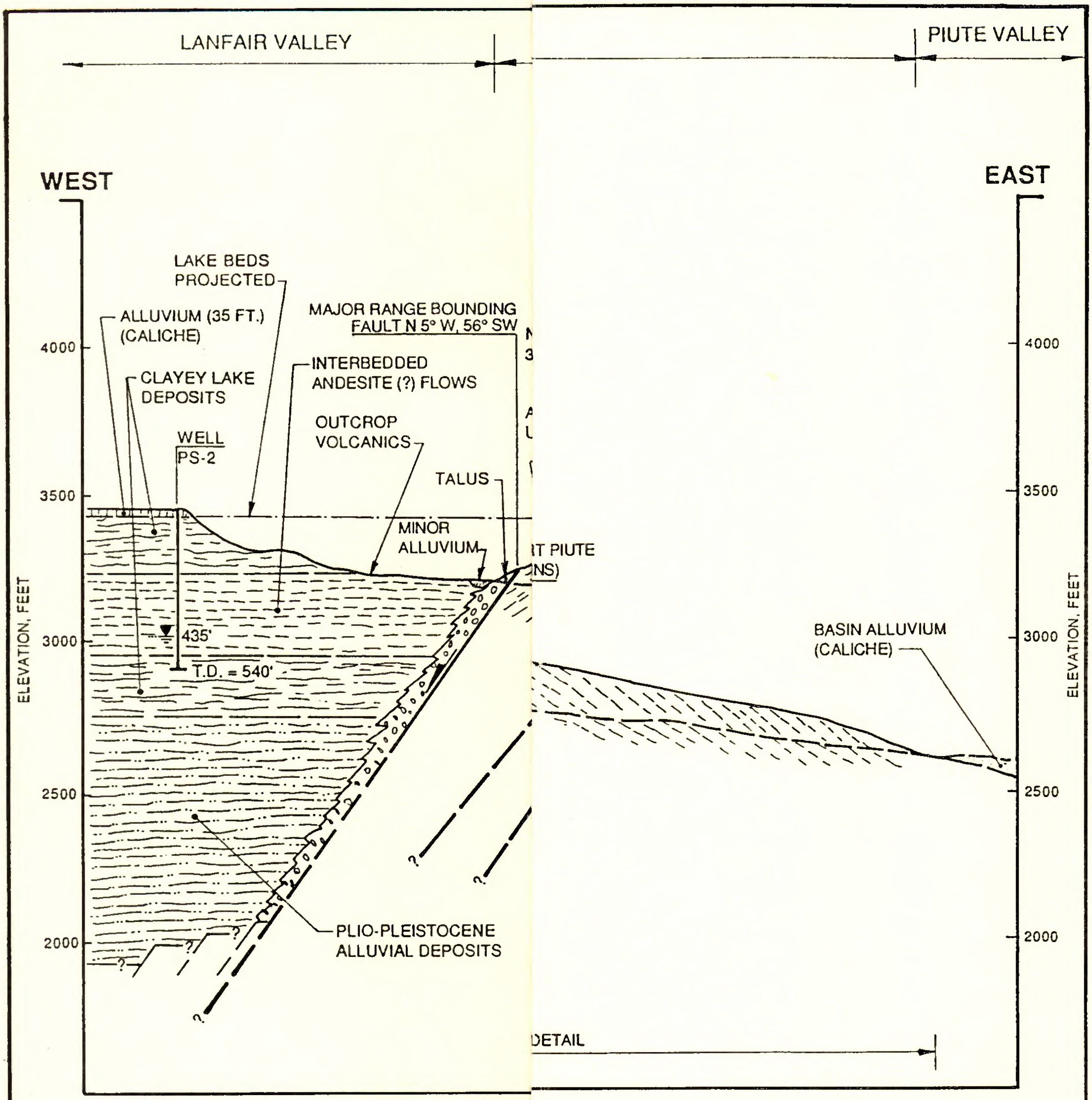
3.2.4 PIUTE GORGE GEOLOGY

1. Piute Gorge is an east-west, irregular-shaped, deeply incised stream channel that drains surface flows from a small drainage area in the southeastern Lanfair Valley, through the southern end of the Piute Range eastward into Piute Valley. The Piute Range at this location is about 1.5 miles wide and up to 700 feet above the Piute Valley. The stream floor varies from a few feet to a few tens of feet in width and has very steep side slopes.

2. The ephemeral canyon drainage above Piute Spring captures a small amount of Lanfair Valley surface drainage from a small 5-square mile watershed area adjacent to the Piute Range. A 300-foot deep, 1.5-mile long by 0.5-mile wide, canyon has been eroded into the floor of Lanfair Valley at this location. This eroded area has moderate to high side slope relief and rather flat floor. Pleistocene age lake beds are exposed continuously along the walls. A 20- to 30-foot thick section of caliche (mostly gravels) mantles the lake beds forming a hard resistant layer.

3. Figure 3.6 shows a cross-section of geologic conditions observed along the canyon axis. Andesitic volcanic flows and interbedded welded tuff breccias are exposed continuously along the canyon walls, through the Piute Range. Locally, bedrock is exposed on the canyon floor, especially at water fall and plunge pool locations. The bedrock varies from relatively fresh and very fractured to very weathered and massive. Approximately 80 percent of the exposed rock above Piute Springs was judged to be very fractured and could have a relatively high hydraulic conductivity for bedrock. Twenty percent of the rock was judged to have a moderately low hydraulic conductivity, due to weathering and its massive character.

4. Numerous normal tensional faults were mapped trending north-south and dipping westward at 50 degrees or higher within the Canyon. All faults display displacement dipping down to the west with a few to several hundred feet of vertical offset. Faulting has caused the section to repeat a few times as observed along the canyon bottom. Clay gouge and brecciated zones several feet thick lie parallel to the fault planes and are, in general, well cemented. The local relief within the range (i.e., canyons and ridges) is obviously controlled by this faulting. East-west trending faults also were observed, most likely representing zones of weakness along which drainages have developed, especially near Piute Spring. A major west dipping fault which bounds the range was noted at the upper gorge mouth and appears to juxtapose alluvial-lake deposits of Lanfair Valley against the volcanics that comprise the Piute Range.



EXPLANATIONS

- APPARENT UPLIFT OF RANGE HAS OCCURRED ALONG THE LANFAIR RANGE BOUNDING FAULT, RESULTING IN TILTING (DOWN TO THE EAST). SUBSEQUENT GRAVITY-TENSIONAL DOWNDROPPING OF BLOCKS TOWARD THE WEST AND WEST OF PIUTE SPRINGS FAULT (LATE MIOCENE TO PLIOCENE).
- UPLIFT OF PIUTE RANGE AND SUBSEQUENT NORMAL FAULTING CAUSED CLOSURE OF LANDFAIR VALLEY ON EAST SIDE, ALLOWING LAKE AND INTERBEDDED VOLCANICS (QUATERNARY) DEPOSITS TO ACCUMULATE.

SOURCE: BASED UPON GEOLOGIC FIELD MAPPING BY ENVIRON

FIGURE 3.6

CONCEPTUAL GEOLOGIC CROSS-SECTION THROUGH PIUTE GORGE

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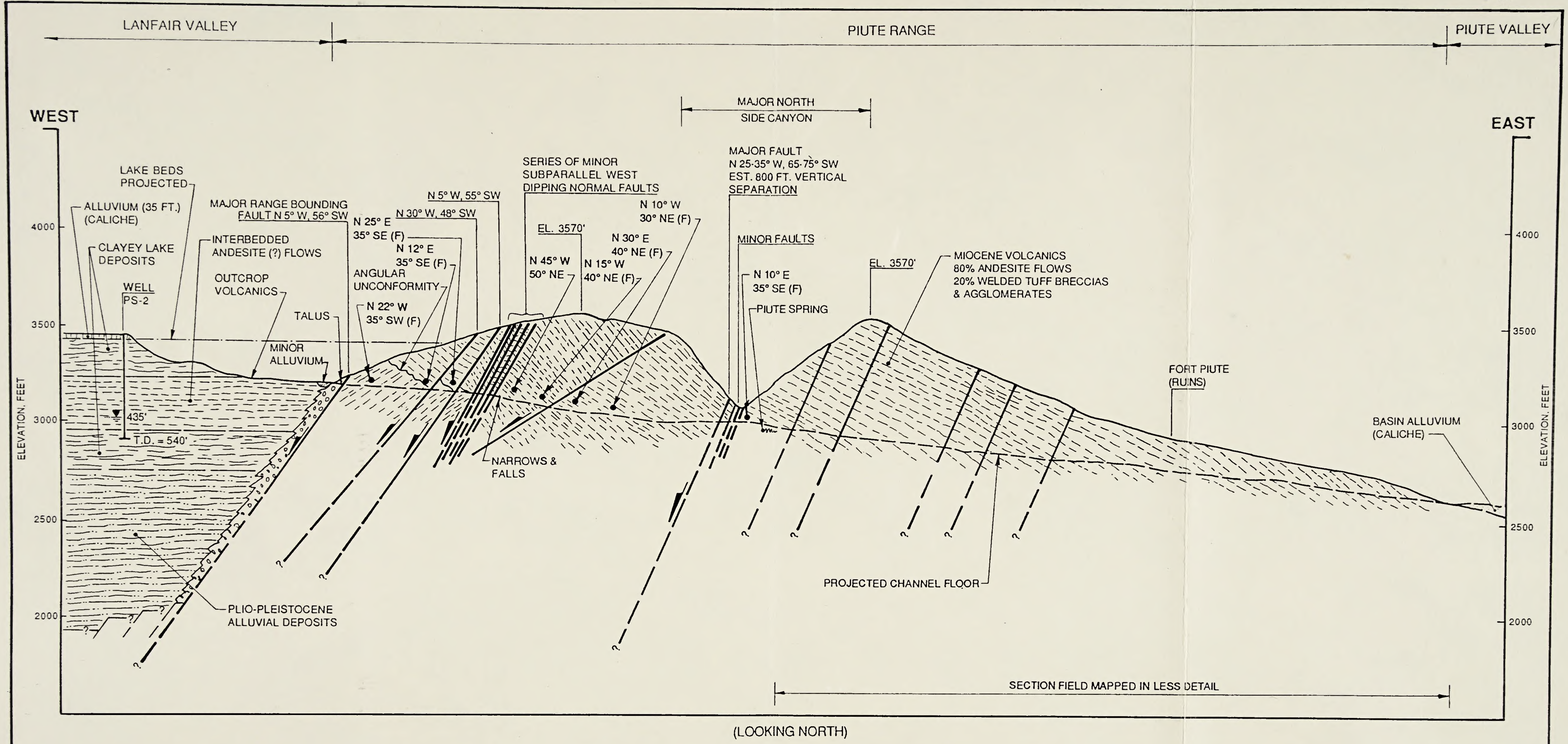
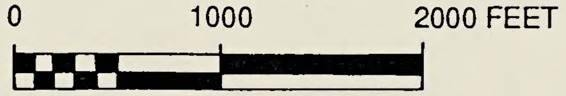


EXPLANATIONS

- APPARENT UPLIFT OF RANGE HAS OCCURRED ALONG THE LANFAIR RANGE BOUNDING FAULT, RESULTING IN TILTING (DOWN TO THE EAST). SUBSEQUENT GRAVITY-TENSIONAL DOWNDROPPING OF BLOCKS TOWARD THE WEST AND WEST OF PIUTE SPRINGS FAULT (LATE MIOCENE TO PLIOCENE).
- UPLIFT OF PIUTE RANGE AND SUBSEQUENT NORMAL FAULTING CAUSED CLOSURE OF LANDFAIR VALLEY ON EAST SIDE, ALLOWING LAKE AND INTERBEDDED VOLCANICS (QUATERNARY) DEPOSITS TO ACCUMULATE.
- WATER GAP WAS FORMED (PIUTE SPRINGS CANYON) BY CONTINUED HEADWARD AND DOWNWARD EROSION FROM PIUTE VALLEY, CAUSING MINOR BEHEADING OF SOME SURFACE DRAINAGE IN LANFAIR VALLEY.
- THE INTERBEDDED VOLCANICS/LAKE DEPOSITS ARE ASSUMED TO BE QUATERNARY AGE. NO SALINE DEPOSITS HAVE BEEN REPORTED. QUATERNARY SECTION ESTIMATED TO BE AT LEAST 1000 FEET THICK.

LEGEND

———	MAPPED FAULT
– – – –	INFERRED FAULT LOCATION
N. 45° W 50° NE	STRIKE AND DIP OF FAULT OR STRATUM



HORIZONTAL SCALE

SOURCE: BASED UPON GEOLOGIC FIELD MAPPING BY ENVIRONMENTAL SOLUTIONS, INC. 1988

FIGURE 3.6

CONCEPTUAL GEOLOGIC CROSS-SECTION THROUGH PIUTE GORGE

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5. The gradient of Piute Gorge floor is relatively steep. A local steepening is apparent just above and continuing east of first point of emittance of Piute Spring and appears to be fault controlled.

6. Piute Spring can be considered a bedrock spring (resulting from flow through the volcanic bedrock) although some alluvium has been deposited in the floor of the canyon and downstream as it blends into alluvium in the Piute Valley.

3.3 HYDROGEOLOGIC SETTING

1. This section describes hydrogeologic conditions in the Lanfair Valley which will determine how the alluvial aquifer would perform during and after pumping and how the extraction of water could affect areas away from the well field. The discussion describes the subsurface data which is available and how that data is extrapolated to describe hydrologic conditions throughout the basin. Assumptions made when necessary are directed toward being conservative with regard to the potential for the proposed pumping to affect Piute Spring. The discussion is presented in the following Sections:

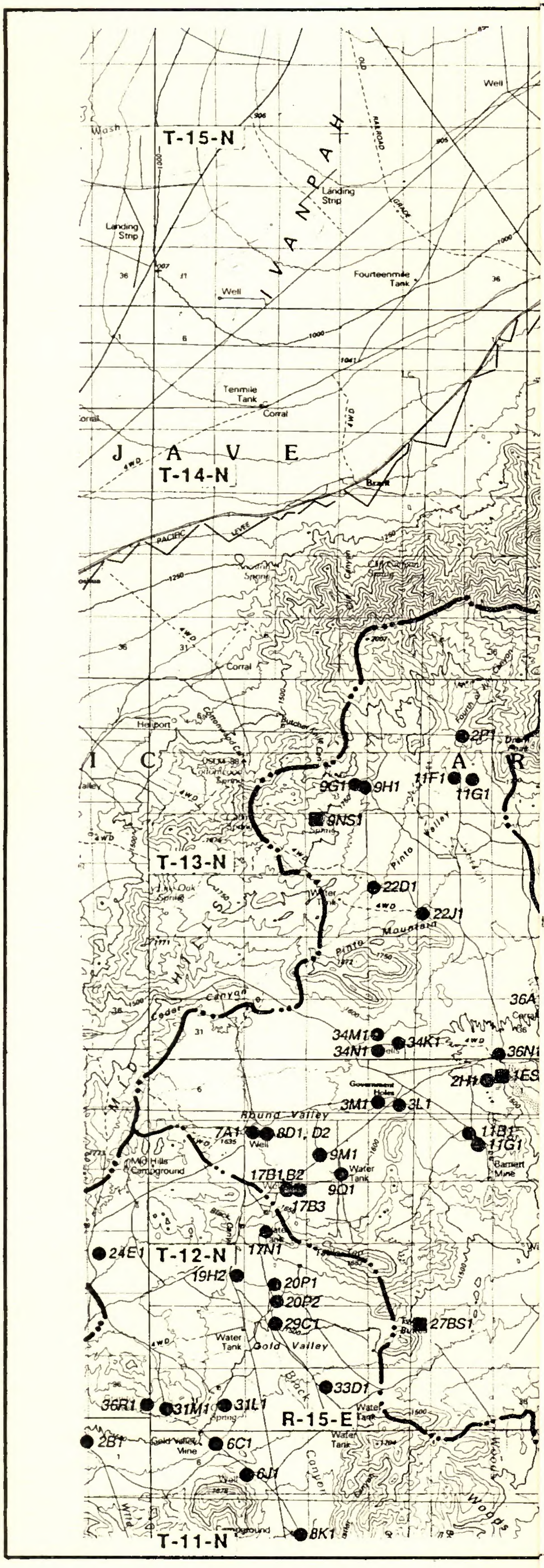
   - Section 3.3.1 - Well Inventory
   - Section 3.3.2 - Lithologic Log Inventory
   - Section 3.3.3 - Spring Inventory
   - Section 3.3.4 - Aquifer Characteristics
   - Section 3.3.5 - Potentiometric Surface
   - Section 3.3.6 - Saturated Thickness

   Section 3.4 describes hydrologic properties of the soils and rock and Section 3.5 describes water balance conditions for the basin.

3.3.1 WELL INVENTORY

1. Figure 3.7 shows the locations where data are available for wells, borings with lithologic logs, and springs in the Lanfair Valley. Tables B.1, B.2, and B.3 in Appendix B summarize specific data known for each well, log, and spring, respectively. The well data in Table B.1 include available ground water depths and elevation information.

2. A significant number of the existing wells are located in the western portion of the Valley where the depth to water is the shallowest. These wells are generally not drilled into the deep alluvial basin and are low production wells with windmills, jack pumps, and gasoline



LEGEND

9NS1	■	SPRING DATA WITH SPRING IDENTIFICATION NUMBER
PS-1	▲	LITHOLOGIC LOGS WITH LOG IDENTIFICATION NUMBER
19C2	●	WATER LEVEL DATA WITH WELL IDENTIFICATION NUMBER
PS-3	●	COMBINED LITHOLOGIC LOG AND WATER LEVEL DATA
	—··—	SURFACE WATER DRAINAGE DIVIDE

BASE REFERENCE: U.S.G.S. 30 x 60 MINUTE SERIES TOPOGRAPHIC MAPS OF IVANPAH, CALIFORNIA, AND DAVIS DAM, NEVADA, BOTH DATED 1985

0 2.5 5 MILES

SCALE

CONTOUR INTERVAL: 50 METERS

FIGURE 3.7

LOCATION OF WELL AND SPRING DATA POINTS

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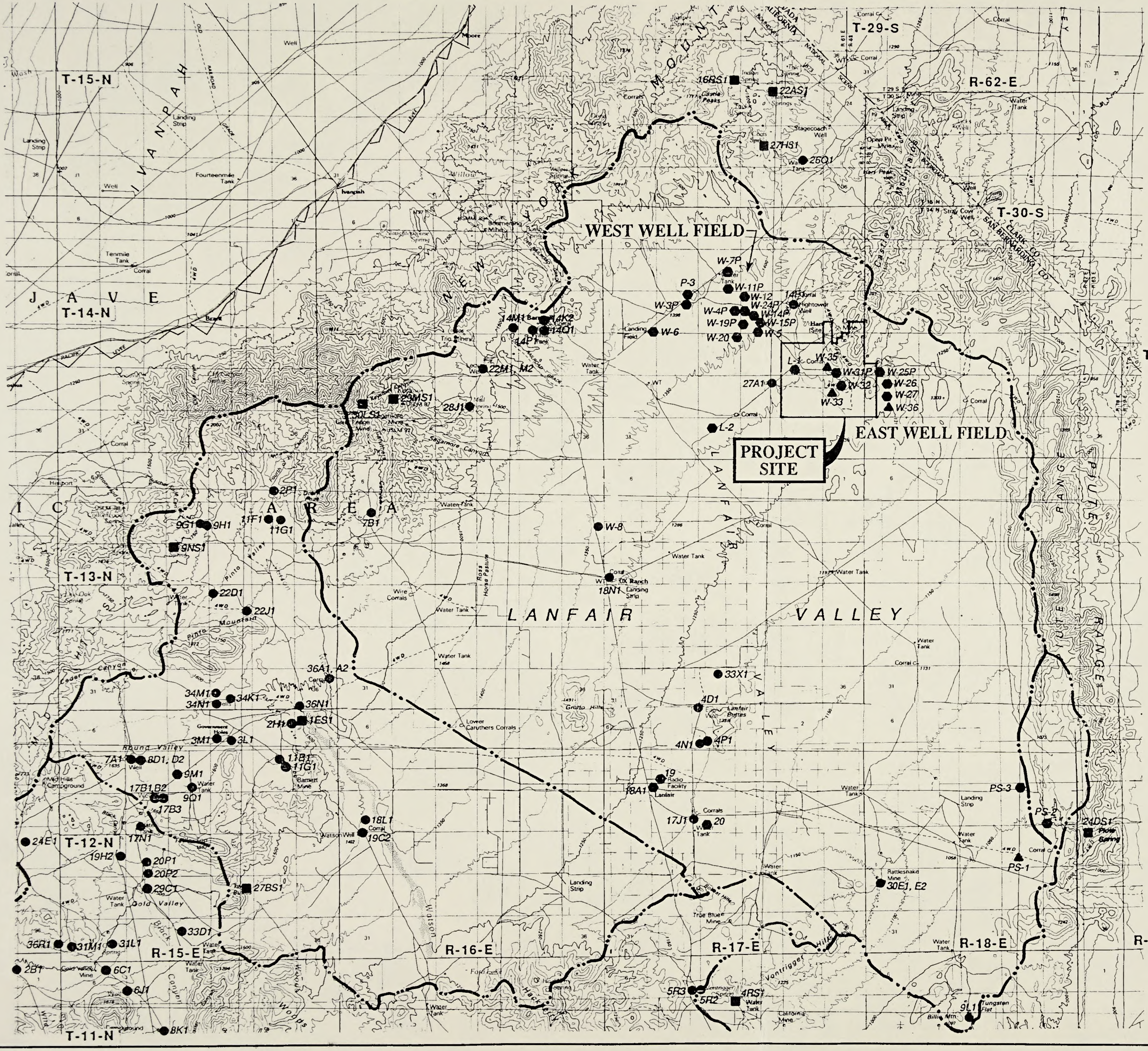

LEGEND

9NS1	■	SPRING DATA WITH SPRING IDENTIFICATION NUMBER
PS-1	▲	LITHOLOGIC LOGS WITH LOG IDENTIFICATION NUMBER
19C2	●	WATER LEVEL DATA WITH WELL IDENTIFICATION NUMBER
PS-3	●	COMBINED LITHOLOGIC LOG AND WATER LEVEL DATA
	—··—	SURFACE WATER DRAINAGE DIVIDE

BASE REFERENCE: U.S.G.S. 30 x 60 MINUTE SERIES TOPOGRAPHIC MAPS OF IVANPAH, CALIFORNIA, AND DAVIS DAM, NEVADA, BOTH DATED 1985

0 2.5 5 MILES

SCALE

CONTOUR INTERVAL: 50 METERS

FIGURE 3.7

LOCATION OF WELL AND SPRING DATA POINTS

CASTLE MOUNTAIN PROJECT

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powered pumps used primarily by ranchers for livestock. Most wells in the northern portion of the Valley and adjacent to the Piute Spring area have been drilled as part of investigations for the proposed project. These wells are in a variety of subsurface conditions. The wells in the south central and southeast portion of the Valley are typically in shallower bedrock areas.

3. Although these existing wells do provide a substantial amount of data for this otherwise remote area, some areas within the basin have few wells, providing limited data. In particular, data are incomplete concerning: (1) a north-south trending ridge of high bedrock which may exist between the Castle Mountains and Hackberry Mountains, (2) the transition from sandy-gravelly alluvium at the West Well Field area to lake bed deposits near to the Piute Spring area, and (3) the depth beneath the lake bed deposits to which more sandy and gravelly alluvium exists above bedrock. To be conservative in evaluating potential impacts of the proposed pumping on Piute Spring, it is assumed that conditions do not occur to the degree that they would hydraulically separate the two areas. If separating conditions did exist, the questions concerning operational impact at the spring would be less important.

4. Well identification in Figure 3.7 follows that of the previous reports. Freiwald (1984) and California Department of Water Resources (1956) use the conventional USGS well numbering system, based on locations within a Township, Range, and Section. This numbering system is described in Appendix C. Other investigators (Mark Group, Mifflin & Associates, Thompson) have used a sequential numbering system, related specifically to their activities.

5. The water level data for wells reported by Freiwald are considered to have a high confidence level because those wells existed for a considerable time before the measurements were obtained. Water level elevations in more recently drilled wells, for the proposed project investigations, are qualified by footnotes on Table B.1 to indicate the level of confidence which may be placed on the data, for reasons discussed below.

6. The wells recently drilled by The Mark Group have the prefixes W-#, W-#P, and PS-#. The W-# wells were exploration borings that did not produce enough water to warrant further work and were subsequently abandoned. The reported depth to water during drilling for these wells does not have a high confidence level since they were not completed or allowed to equilibrate. Information from the W-#P wells have a high level of confidence since these wells were completed and subsequent equilibrated water levels have been obtained.

7. The PS-# holes were drilled upgradient of Piute Spring to assist in evaluating the potential relationship between Lanfair Valley ground water and the spring. PS-1 caved in before it could be completed and before a water level could be obtained. PS-3 was not completed as a monitoring well, but the indicated water level is shown in the high confidence level category since successive recordings were taken to assure that the water level had equilibrated. PS-2 was completed with 2-inch PVC piping and the water level data for PS-2 is also considered to have a fairly high confidence rating. However, the data may not be totally accurate because the casing is too small to fully remove drilling mud and complete the well.

8. Mifflin & Associates, Inc. had three ground water exploration test borings (L-1, L-2, and P-3) drilled in 1987. Test boring L-1 is located between the East and West Well Fields and indicated a perched water level of 219 feet during drilling, but which dropped to 453 feet as the depth of the hole was increased. L-2 is located to the south of the West Well Field and was logged as being dry to a total depth of 680 feet. P-3, located in the western portion of the West Well Field, had a consistent water level reading of 493 feet as the depth of the hole was increased. Confidence in water levels for these holes is not high since they were not developed and have been abandoned.

9. Thompson's (1921) well and spring data are numbered sequentially (1 to 23). The precise location of data points is not given. Most of this older information is covered more thoroughly in Freiwald's report.

3.3.2 LITHOLOGIC LOG INVENTORY

1. Table B.2 in Appendix B summarizes the inventory of holes for which lithologic data is available. The log information is generally related to the following areas:

   - The proposed East and West Well Fields
   - The vicinity of Piute Spring
   - Vicinity of Lanfair Buttes

   Most of these lithologic logs (prepared by geologists) were generated as a result of investigations for the proposed Castle Mountain project. The Piute Spring area logs are supplemented with geologic mapping of the deep, incised canyon in the valley alluvium, and outcrops along the Piute Gorge.

2. There are fifteen logs in the area of the West Well Field and eight in the East Well Field. The logs in the West Well Field are for holes ranging in depth between 688 and 1,125 feet. The alluvial materials consist of a full range of sandy gravels, clayey gravels, gravelly sands, clayey sands, sandy clays, silty sands, sand, clay, and other variations. They have different degrees of cementation, induration, angularity, and gradation. The deposits are variable over short distances so that direct correlations cannot be made among wells. A volcanic unit was found to underlie the alluvium in eleven of these wells, at depths ranging from 515 to 730 feet. In four wells, no volcanics were encountered, including three which penetrate to a depth of 1,000 feet. Two wells penetrated through the volcanics and back into unconsolidated sediments. The volcanics are characterized as dark, grey-green andesite that has been altered to some degree and sometimes exists with interbedded clay.

3. The logs from wells in the East Well Field varied in depth from 640 to 1,055 feet and indicate these wells are predominantly in volcanic bedrock. Four holes were drilled entirely in volcanics and four holes encountered interbedded alluvium and volcanics. The volcanic materials consist mainly of andesite with various degrees of alteration and clay content, although some rhyolite and basalt are present. The interbedded alluvium consists of sandy clays, sandy gravels, and clay. The zones of alluvium occurring between the volcanic flows are relatively thin, ranging from 10 to 75 feet in thickness.

4. The well log for L-1, located between the East and West Well Fields, indicates that there is a coarse alluvium for the first 20 feet followed by 520 feet of mudstone and 235 feet of volcanics. As noted above, perched water was noted at a depth of 219 feet during drilling of this hole, but the water level fell to a depth of 453 feet when the depth of the hole was increased.

5. The logs from the three holes located near Piute Spring generally show a predominance of clays in contrast to the holes at the West Well Field. This condition agrees with observations of lake bed deposits at the incised canyon, which drains into the Piute Gorge. The log for the hole closest to the spring (PS-2) penetrated a 260-foot thick dark volcanic layer at a depth of 240 feet which was underlain by more clay to a total hole depth of 580 feet. PS-3, toward the northwest, encountered sandy soil for the top 280 feet and then clay to a total depth of 600 feet. PS-1, toward the southwest, consisted of clayey soil for its entire depth of 540 feet. None of these holes penetrated to older alluvium expected to occur in the southeastern portion of the basin or into bedrock.

6. Thompson (1921) reports two wells with logs near Lanfair Buttes (19 and 20), in the south-central portion of the basin. These logs show that there is a thin layer of gravel at the surface underlain by a thick layer of volcanic ash (greater than 400 feet thick) and then gravel beneath the ash. Thompson indicates that the ash may include tuff, rhyolite, or other extrusive rocks.

7. One hole with a log in central Lanfair Valley (W-8) penetrated alluvium consisting of sand and gravel with clay for its entire depth of 480 feet. Water was not encountered in this hole.

3.3.3 SPRING INVENTORY

1. A number of springs are found in the mountain regions around Lanfair Valley. Generally, springs in this type of shallow bedrock are located along faults and formation contacts which restrict the downward percolation of infiltrated water. Table B.3 in Appendix B summarizes those springs which have flow data. Other springs have had reported flow at various times in the past, but the most recent data show them to be essentially dry (Freiwald, 1984, Thompson, 1921). The most recent measurements indicate that the typical spring flow is 2 gpm or less, with the exception of Piute Spring which flows at about 40 gpm at its point of first emittance and much higher at downstream locations.

2. With the exception of Piute Spring, the springs inventoried are geologically above the Lanfair Valley alluvium, and in the recharge zone of the basin. Usually, the source of water for these types of springs is from direct infiltration into the rock, before it flows downgradient into the alluvium. Therefore, changes in water levels in the alluvium do not have the potential to affect spring flow conditions. Piute Spring represents a different condition. This spring emits from a rock formation, but at an elevation which is lower than the ground water level in Lanfair Valley. As discussed later in this report, it is probable that Piute Spring flow is related to ground water conditions in the alluvium.

3.3.4 AQUIFER CHARACTERISTICS

3.3.4.1 Alluvial Aquifer

1. The alluvial aquifer in the Lanfair Valley is similar to other aquifers which characteristically exist in the southwest desert region. The sequence of aquifer material is lenticular with the various layers or lenses having variable amounts of silt and clay. This results in a condition where horizontal permeability is much higher than the vertical permeability. Typically, the

general grain size is coarsest near the mountains and highlands and become finer toward the center of the basin because silts and clays travel furthest before settling.

2. This type of aquifer behaves as a semi-confined system. In general, the system is expected to behave as an unconfined system because layers of finer grained material are not continuous. Over short distances, the system will behave as a confined aquifer for short pumping periods while a fine grained lens locally confines underlying ground water. Eventually, as water drains from the coarser grain lenses, the water levels drop below the confining unit and then the system behaves as an unconfined aquifer.

3. A semi-confined condition is evident in the West Well Field. The logs do not show a thick or continuous confining layer above the ground water level. However, static water levels are frequently higher than the level reported during drilling, indicating some amount of localized confinement. The reported rise in water levels after drilling have been:

Well	Driller's Report of Depth to Water (Ft)	Static Water Level (Ft)	Rise in Head
W-3P	520	483	37
W-4P	415	390	25
W-7P	485	474	11
W-11P	480	428	52
W-14P	380	359	21
W-15P	400	338	62
W-18P	360	330	30
W-19P	400	360	40

4. Based on these data, it is anticipated that the aquifer may behave as a confined system until the water level is lowered approximately 30 to 60 feet. Then the system should behave primarily as an unconfined system. The Mark Group (1988) has observed this type of behavior during the 72-hour aquifer pump tests recently conducted in the West Well Field. They explain this semi-confined condition is commonly known as "delayed yield." The Mark Group provides a comprehensive discussion and references for this behavior in their 1988 report.

3.3.4.2 Potential Consolidated Bedrock Aquifers

1. The consolidated bedrock surrounding the alluvial valley consists mainly of volcanics and metamorphic units with interbedded sands, gravels, clays, and ash flows. The volcanics are Tertiary in age and are generally andesite with some rhyolite, and basalt. Mesozoic granite is

dominant in the western highlands and Precambrian metamorphic rocks are found in the Vontrigger Hills. An area of Paleozoic limestones which overlay the younger Mesozoic granites is present in the southeastern portion of the New York Mountains.

2. The most important bedrock areas for the purpose of this study are the Castle Mountain and Piute Range volcanics. The East Well Field is located at the south end of the Castle Mountains. A small portion of water required for the proposed project may be obtained from wells drilled into volcanic rock in this area.

3. The Piute Range would not be used for water supply wells. However, hydraulic properties of that rock are useful for evaluating how underflow from the Lanfair Valley toward the Piute Valley occurs. The volcanic rocks at the Castle Mountains and Piute Range are of the same basic origin and are expected to have similar basic hydraulic properties. The Piute Range bedrock may be more permeable in its present state, however, because fractures and faulting is more extensive there because of stresses and displacements which occurred during the uplifting of that range, and fracture filling by weathering is less advanced because the uplifting of the Piute Range occurred more recently.

3.3.5 POTENTIOMETRIC SURFACE

1. Figure 3.8 shows the plot of the potentiometric surface or ground water table surface for the Lanfair Valley as interpreted from the available well data. The map was prepared using: (1) linear interpolation between points of known water surface elevation from well data, (2) reasonable assumptions for flow direction conditions of the basic boundaries, and (3) interpolation of conditions between locations of known conditions.

2. In general, the ground water slope conforms with surface topography as is typical for many large alluvial basins. The ground water flow direction for the large northeastern portion of the basin is generally toward the east and southeast, where discharge would occur as underflow to the Piute Valley. Some of this flow also occurs through the Sacramento Wash area into the Fenner Valley.

3. The ground water contour data for the southwestern portion of the Lanfair Valley indicate that most of this portion of the Lanfair Valley basin discharges as underflow into the adjacent Fenner Valley to the south.

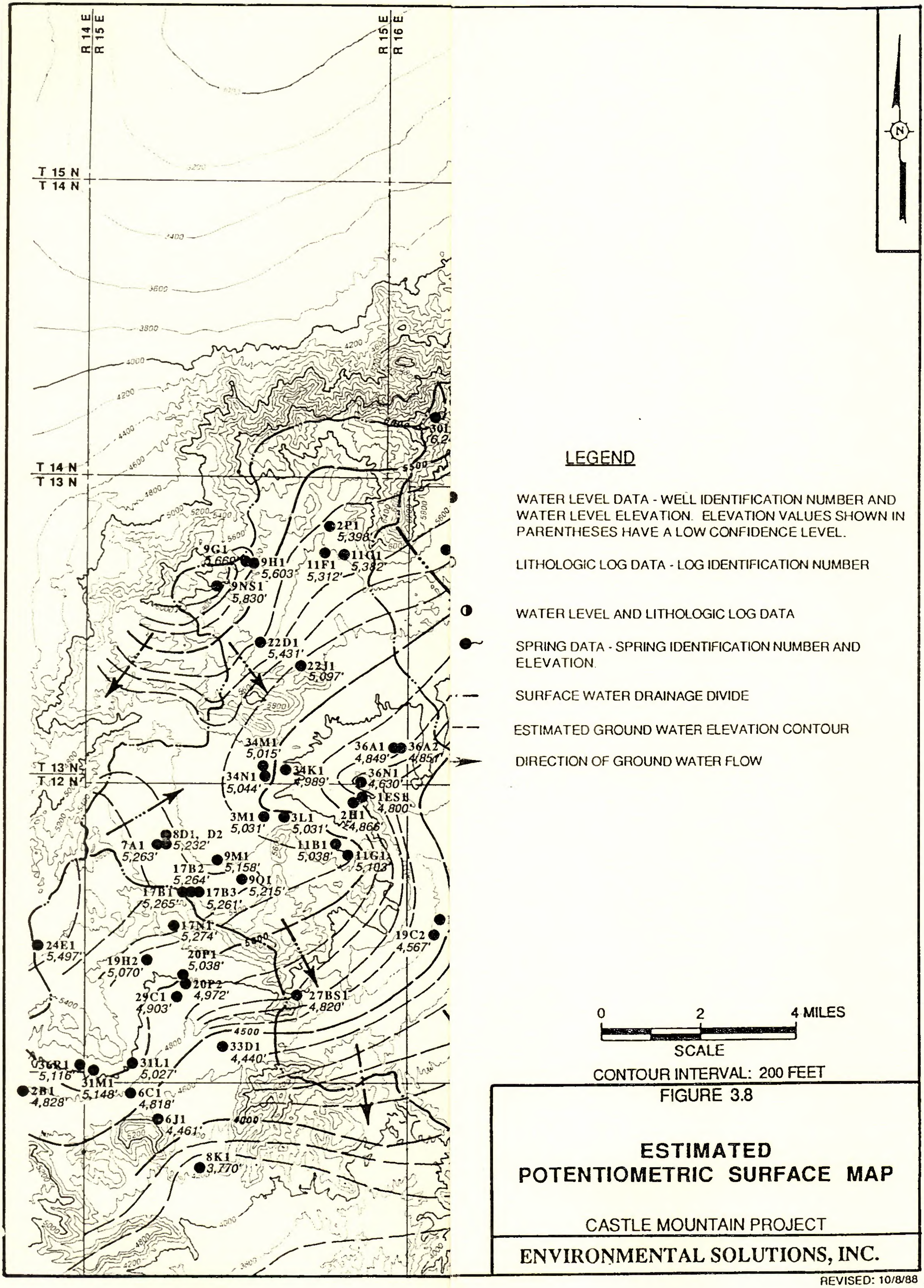

FIGURE 3.8

ESTIMATED POTENTIOMETRIC SURFACE MAP

CASTLE MOUNTAIN PROJECT

ENVIRONMENTAL SOLUTIONS, INC.

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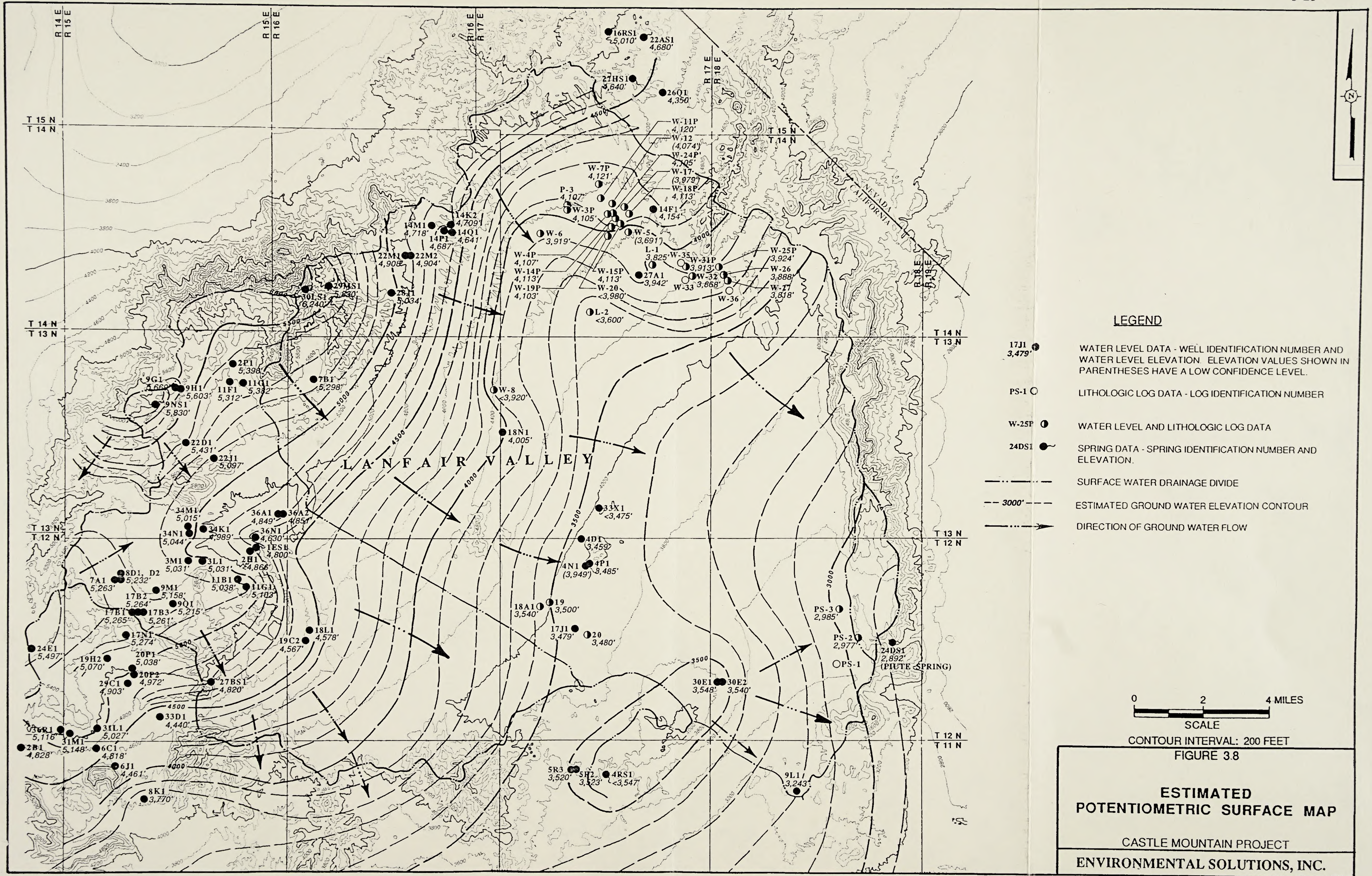

LEGEND

17J1 ● 3,479'	WATER LEVEL DATA - WELL IDENTIFICATION NUMBER AND WATER LEVEL ELEVATION. ELEVATION VALUES SHOWN IN PARENTHESES HAVE A LOW CONFIDENCE LEVEL.
PS-1 ○	LITHOLOGIC LOG DATA - LOG IDENTIFICATION NUMBER
W-25P ◐	WATER LEVEL AND LITHOLOGIC LOG DATA
24DS1 ●	SPRING DATA - SPRING IDENTIFICATION NUMBER AND ELEVATION.
—··—	SURFACE WATER DRAINAGE DIVIDE
-- 3000' --	ESTIMATED GROUND WATER ELEVATION CONTOUR
—··→	DIRECTION OF GROUND WATER FLOW

0 2 4 MILES

SCALE

CONTOUR INTERVAL: 200 FEET

FIGURE 3.8

ESTIMATED POTENTIOMETRIC SURFACE MAP

CASTLE MOUNTAIN PROJECT

ENVIRONMENTAL SOLUTIONS, INC.

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4. The apparent break in slope (from steeper to shallower in the downgradient direction) of the ground water surface in the vicinity of Wells 33X1, 4D1, and 4P1 represent a notable feature for the gradient toward Piute Spring and the Piute Range. This break in slope occurs near the same location that a break in slope occurs in the surface topography, except the change in potentiometric slope is greater. This location also occurs approximately at the location where a zone of high bedrock may occur between the Castle Mountains and Hackberry Mountain (see Section 3.2.1).

5. The break in gradient of the potentiometric surface indicates some change in subsurface conditions which could affect flow conditions in that direction. For a basin with continuous ground water flow in the direction of the break in slope, such a condition indicates an increase in permeability and/or aquifer thickness. The existence of lake bed deposits at relatively shallow depths upgradient from the spring area indicates that the overall basin thickness probably increases toward the east-southeast and more sandy and gravelly alluvium underlies the lake bed deposits. In modeling of the basin, the effect of this condition could be accounted for by allowing increases in either parameter.

3.3.6 SATURATED THICKNESS

1. Except at areas near the perimeter of the basin, where bedrock is shallow, most of the borings and wells did not extend to the bedrock below basin fill material. Therefore, data on the exact thickness of the basin fill is not available. To some extent, this makes analyses discussed in this report conservative, because the available reservoir of stored ground water may be larger than considered.

2. Table 3.1 shows saturated thickness information for borings and wells in the vicinity of the proposed West Well Field. The saturated thickness for each boring or well is evaluated considering both: (1) the entire depth of the hole, and (2) the alluvium portion of the hole below the water table, without consideration of the volcanic rock. The data shown in bold on the table are for holes with the highest level of confidence for water level conditions.

3. Well W-11P indicates that the saturated thickness, not considering volcanic rock, is greater than 667 feet at some portions of the basin. Well W-25P indicates a saturated thickness of greater than 724 feet when the volcanic rock is involved. These data indicate that the saturated thickness in the well field may exceed 700 feet. However, the Mark Group (personal communication) has indicated that during drilling, water production did not appear

TABLE 3.1 - SATURATED THICKNESS ESTIMATES

Well Identification	Source	Total Depth (Ft)	Depth to Water (Ft)	Saturated Thickness Including Volcanics (Ft)	Position of Volcanics (TD=total depth)	Thickness of Volcanics below water level (Ft)	Saturated Thickness without Volcanics (Ft)
W-3P	**Mark Group**	**734**	**483**	**>251**	**726-734 TD**	**8**	**>243**
W-4P	**Mark Group**	**1000**	**390**	**>610**	**710-1000 TD**	**290**	**>320**
W-5	Mark Group	1020	710(c)	>310	445-700	0	>310
W-6	Mark Group	1000	630(c)	>370	425-500	0	>370
W-7P	**Mark Group**	**1000**	**474**	**>526**	**none**	**0**	**>526**
W-8	Mark Group	480	>480(c)	no data	none	0	no data
W-11P	**Mark Group**	**1125**	**428**	**>697**	**1095-1125 TD**	**30**	**>667**
W-12	Mark Group	1000	435(c)	>565	none	0	>565
W-14P	**Mark Group**	**700**	**359**	**>341**	**605-700 TD**	**95**	**>246**
W-15P	**Mark Group**	**1000**	**338**	**>662**	**590-1000 TD**	**410**	**>252**
W-17	Mark Group	1000	500(c)	>500	none	0	>500
W-18P	**Mark Group**	**720**	**330**	**>390**	**515-540, 575-720 TD**	**170**	**>220**
W-19P	**Mark Group**	**1000**	**360**	**>640**	**600-1000 TD**	**400**	**>240**
W-20	Mark Group	980	460(c)	>520	580-980 TD	400	>120
W-24P	**Mark Group**	**688**	**383**	**>305**	**none**	**0**	**>305**
W-25P	**Mark Group**	**1000**	**276**	**>724**	**224-735, 750-815, 830-865, 905-1000TD**	**654**	**>70**
W-26	Mark Group	640	280(c)	>360	340-640 TD	300	>60
W-27	Mark Group	1000	320(c)	>680	485-660,670-760,835-1000TD	430	>250
W-31P	**Mark Group**	**897**	**345**	**>552**	**all volcanic, basalt at 820 TD**	**475**	**>77**
W-32	Mark Group	1040	380(c)	>660	all volcanic	660	no data
W-33	Mark Group	1000	600(c)	>400	all volcanic	400	no data
W-35	Mark Group	1055	>1055(c)	no data	all volcanic	0	no data
W-36	Mark Group	1010	>1010(c)	no data	0-420, 495-1010TD	0	no data
PS-1	Mark Group	600	NA	no data	none	0	no data
PS-2	Mark Group	580	432	>148	235-495	63	>85
PS-3	Mark Group	600	455	>145	none	0	>145
L-1	Mifflin & Assoc.	775	453	>322	540-775 TD	235	>87
L-2	Mifflin & Assoc.	680	>680	no data	0-285	0	no data
P-3	Mifflin & Assoc.	820	493	>237	730-820TD	90	>147
20	Thompson	550	400	>150	volcanic ash 4-410	10	>140
19(b)	Thompson	550	500	>50	volcanic ash 52-520	20	>30
12N/17E-8X1(b)	California DWR	550	NA	no data	volcanic ash 52-520	20	no data
12N/17E-18A1(b	Freiwald	550	500	>50	volcanic ash 52-520	20	>30

Note: Bold print indicates higher confidence level

(a) approximate value taken from topographic map

(b) These three logs are identical. May be same well although location and elevation is unclear. Freiwald reports section 18 while Thompson and California DWR report as being located in section 8.

(c) Depth to water during drilling, these holes abandoned prior to water level equilibration.

to increase appreciably for the lower portion of wells which were drilled to depths exceeding about 700 feet from the ground surface.

4. For modeling purposes, it is reasonable to assume that the saturated depth in the vicinity of the West Well Field is in the 600 to 700 feet range. The depth is expected to increase in the direction toward the Piute Range.

5. As discussed in Section 3.2.1, the thickness of alluvium is expected to increase significantly toward the Piute Range, possibly to as much as 1,500 feet. As illustrated in Figure 3.5, the upper portion of the alluvium at the eastern end of the basin consists of lacustrine deposits resulting from lakes which were formed behind the Piute Range. The deepest portion of this alluvium should be sandy and gravelly material deposited before the Piute Range was uplifted. The saturated thickness in the east portion of the basin is expected to exceed 1,000 feet.

6. Also as noted in Section 3.2.1 and in Figure 3.5, there may be a zone of higher bedrock (reduced alluvium thickness) trending in a north-south direction between the Castle Mountains and Hackberry Mountains. For purposes of this study, it is considered to be conservative to assume that such a high bedrock zone does not separate the West Well Field from the Piute Spring area.

3.4 HYDROGEOLOGIC PROPERTIES

1. Aquifer tests conducted by The Mark Group (1987, 1988) in the proposed well field areas have included several short-term (e.g., 24-hour) single well aquifer tests conducted in the borings with the highest potential to function as production wells in the West and East Well Fields, and one 72-hour multiple well test in the West Well Field. The 72-hour test was conducted by pumping Wells W-14P, 15P, and 24P, and using six observation wells. Hydrologic properties derived from the test data and the analyses of aquifer conditions are discussed in the following sections:

   - Section 3.4.1 - Transmissivity/Hydraulic Conductivity/Porosity
   - Section 3.4.2 - Storativity

3.4.1 TRANSMISSIVITY/HYDRAULIC CONDUCTIVITY/POROSITY

1. Transmissivities were calculated from aquifer test data using the Jacob Method (Cooper and Jacob, 1946) and then the hydraulic conductivities (or permeabilities) were calculated by

dividing the transmissivity by the aquifer saturated thickness. Since the actual saturated thickness is not known, the minimum saturated thickness (Table 3.1) with and without inclusion of volcanics, were used to calculate hydraulic conductivity range. The values calculated are summarized in the following table:

Well	Well Field	Transmissivity (ft^2/day)	Transmissivity (gpd/ft)	Saturated Thickness (with/without)* (ft)	Hydraulic Conductivity (with/without)* (ft/day)	Hydraulic Conductivity (with/without) (gpd/ft^2)	Hydraulic Conductivity (with/without) (cm/sec x 10^{-4})
W-4P	West	2,750	20,570	610/320	4.5/8.6	33.7/64.3	15.9/30.3
W-7P	West	40	300	526/526	0.08/0.08	0.6/0.6	0.3/0.3
W-11P	West	710	5,310	697/667	1.0/1.1	7.5/8.2	3.5/3.9
W-14P	West	1,440	10,770	341/246	4.2/5.9	31.4/44.1	14.8/20.8
W-15P	West	1,060	7,930	662/252	1.6/4.2	12/31.4	5.6/14.8
W-18P	West	430	3,220	390/220	1.1/2.0	8.2/15	3.9/7.1
W-24P	West	1,710	12,790	305/305	5.6/5.6	41.9/41.9	19.8/19.8
W-25P	East	70	520	724/70	0.10/1.1	.7/8.2	0.4/3.9
W-31P	East	90	670	552/77	0.15/1.1	1.1/8.2	0.5/3.9

*With volcanics included/without volcanics included.

2. These data indicate that the aquifer near West Well Field has an average transmissivity of about 1,160 ft^2/day (8,680 gpd/ft). The average hydraulic conductivity is 2.6 ft/day (19.4 gpd/ft^2 or 9.1 x 10^{-4} cm/sec), if the volcanics are included, and 3.9 ft/day (29.1 gpd/ft^2 or 1.4 x 10^{-3} cm/sec) if the volcanics are excluded.

3. The East Well Field has a much lower average transmissivity of 80 ft^2/day (600 gpd/ft) and an average permeability of 0.13 ft/day, (1.0 gpd/ft^2 or 4.5 x 10^{-5} cm/sec). This permeability is calculated including the volcanic rock since the East Well Field is primarily in a bedrock zone. Permeability of the bedrock is primarily due to the secondary features including fractures and faults.

4. Porosity values for the materials have not been measured, but can be estimated based upon published ranges for consolidated and unconsolidated materials (Driscoll, 1987). Porosity values for alluvium are estimated to range from 5 to 20 percent depending on grain size and the degree of cementation. Porosity in the volcanic bedrock is estimated to be 0.05 to 0.10 percent depending on the amount of faulting and fracturing or secondary porosity. The highest value of porosity is usually associated with the highest permeability for a particular soil or rock type because the percentage of voids (pathways) affects both parameters.

3.4.2 STORATIVITY

1. The storativity value calculated from the 72-hour aquifer test data is 0.00004. This is typical of values expected for a confined aquifer system, and conflicts with the lithologic data which shows that the aquifer is predominantly unconfined. The Mark Group (1988) has evaluated this short-term condition in considerable detail because of the importance of storativity in estimating aquifer behavior during pumping for the proposed project. Based on these evaluations, including consultation with other experts familiar with similar desert basins, the Mark Group concludes that in the long-term the aquifer will behave as an unconfined system, with a storativity value on the order of 0.1. This difference between short-term pumping test data and long-term behavior in lenticular alluvium is known as "delayed yield."

2. For modeling of the entire basin, discussed in Section 5.5 of this report, the assumption is made that the system will act in a confined manner, with a storativity of 0.0004, until the water level drops 65 feet. Then the storativity value of 0.1, representing an unconfined condition, will be used. The 65-foot dimension is determined from the maximum difference between the depth of water reported during drilling and the static water level, discussed in Section 3.3.4.1.

3.5 WATER BALANCE

1. This section discusses water balance conditions for the Lanfair Valley as related to the evaluation of potential impacts of the proposed water withdrawal. Water balance is considered to be the condition wherein the amount of water naturally recharged to the Lanfair Valley ground water system is equal to: (1) the discharge of water at surface springs and underflow to adjacent areas, and (2) utilization by extraction. Presently, only a small amount of pumping is occurring (approximately 30 acre-feet per year) and it is assumed that the Valley is in a state of water balance equilibrium which has become established over geologic time.

2. Extraction of ground water for the proposed Castle Mountain project would represent a larger change to the natural water balance condition than any previous man-made change. A main purpose of the investigations discussed in this report is to evaluate the potential effects of this change, especially at Piute Spring.

3. Most of the data for estimating recharge to the basin from precipitation is derived from an extensive evaluation undertaken by the Mark Group (1988). Estimates of the amounts and

locations of discharge from the basin are evaluated by the separate analyses discussed in this report. Conditions at Piute Spring are determined from combined efforts by the Mark Group, and Environmental Solutions, Inc., and previous investigations. This discussion is presented in the following sections:

- Section 3.5.1 - Recharge to the Basin.
- Section 3.5.2 - Recharge to the West Well Field Area.
- Section 3.5.3 - Discharge from the Basin.
- Section 3.5.4 - Special Considerations at Piute Spring.

3.5.1 RECHARGE TO THE BASIN

1. Because Lanfair Valley is elevated above adjacent valleys, recharge of ground water by underflow from other basins is not possible. Therefore, it is appropriate to assume that recharge into Lanfair Valley ground water is derived only from the infiltration of precipitation which falls onto the basin area. The primary factors which determine infiltration are:

   - The amount and distribution of rainfall which occurs at various locations throughout the basin.

   - The characteristics of slope and surface soil conditions which determine the rate at which surface runoff and surface infiltration into the soil occurs.

   - The amount of evaporation and evapotranspiration which occurs to draw water back out of the soil pores before infiltration to deeper ground water occurs.

2. The Mark Group shows how these various factors are frequently evaluated by the State of Nevada and the USGS, for desert basins in semi-arid and arid regions, using a procedure known as the Maxey-Eakin (1949) Method. This procedure is based on empirically derived relationships between precipitation and recharge. The most commonly used coefficients are:

Annual Precipitation (inches)	Percentage of Precipitation as Recharge
Less than 8	0
8 to 12	3
12 to 15	7
15 to 20	15
Greater than 20	25

3. Figure 3.9 shows the approximate distribution of rainfall in Lanfair Valley. This data shows that little or no recharge should be anticipated for the entire southeastern portion of the Valley, because precipitation in this lower elevation area is less than eight inches per year. Infiltration to support the natural water balance for the basin would be expected to occur in the north and northwestern portions of the basin where annual precipitation ranges between eight and more than 10 inches per year. The recharge percentage in this entire area would be estimated to be about three percent of precipitation.

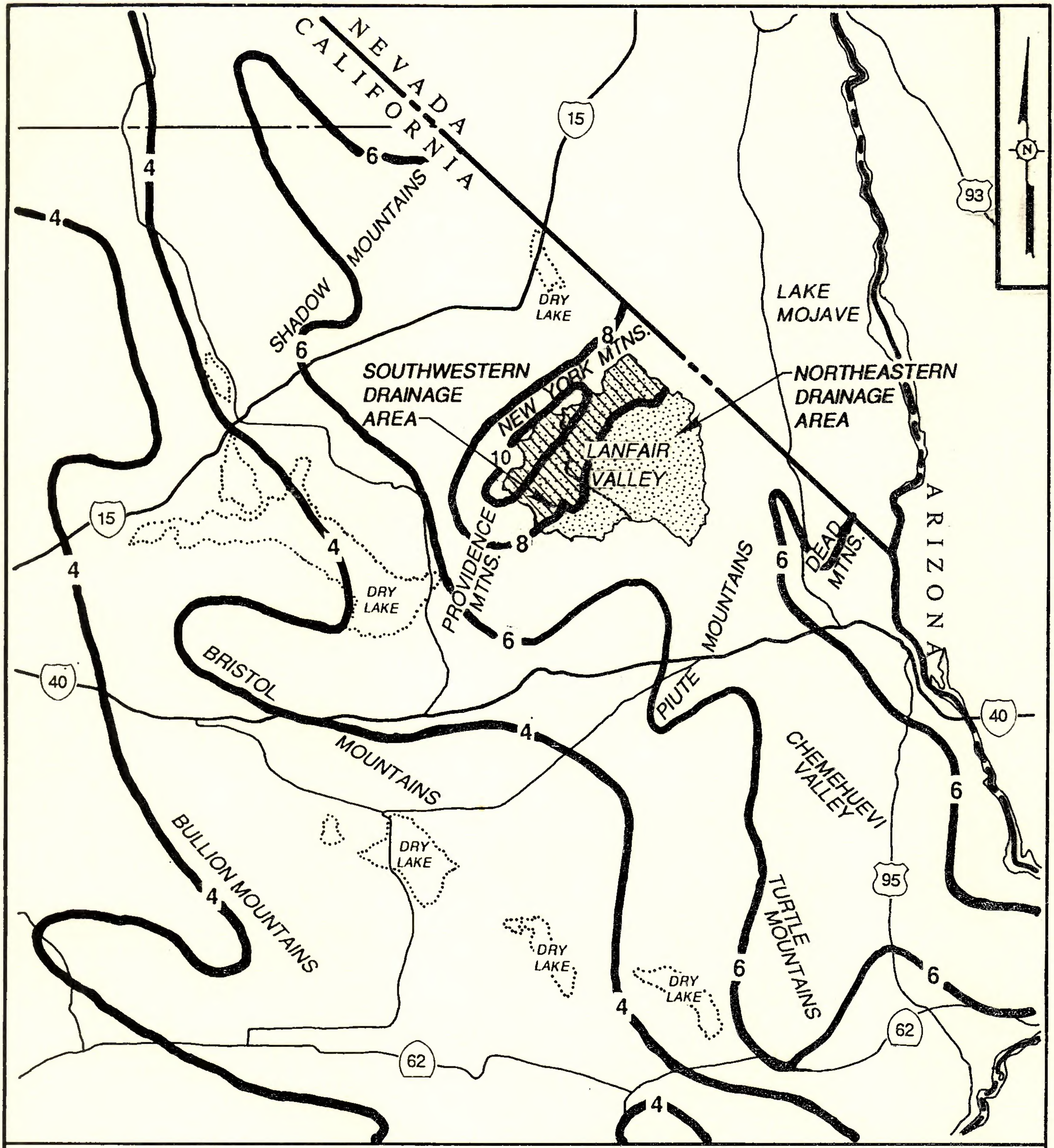
4. The Mark Group estimates recharge to the entire Lanfair basin to be about 3,500 to 4,000 acre-feet per year using the recharge coefficients discussed above and rainfall distributions determined from Freiwald (1984) and Rush and Huxel (1966). In order to evaluate the degree of conservation for the calculations, the Mark Group also examined recharge values which would be realized if alternative recharge assumptions were made. The following three alternative recharge scenarios were evaluated:

   - Estimates of infiltration using only winter precipitation (about 65 percent of annual) to account for several published reports which indicate that mountain-front recharge in this area may be a function of winter precipitation only. This approach results in recharge estimates of 2,300 to 2,600 acre-feet per year using the Maxey-Eakin coefficients.

   - The percent of precipitation as recharge is only one percent for the 8- to 12-inch precipitation zone. This lower coefficient has been used by Walker and Eakin (1963) for the Amargosa Desert in California and Nevada. That basin is at lower elevation and would be expected to have higher rates of evaporation and no snowfall. Recharge estimates for the entire Lanfair basin using the lower Walker and Eakin coefficient are 1,100 to 1,300 acre-feet per year considering the entire annual precipitation.

   - Statistically modified infiltration coefficients, based on regression methods developed by Watson, et al. (1976) determined from the correlation of the Maxey-Eakin coefficients to estimated recharge for 63 basins in Nevada. Estimates of recharge to the Lanfair basin using this procedure vary from 33 to 300 percent higher than those using the Maxey-Eakin coefficients.

5. The values using the regression methods are considered to be unrealistically high, especially for performing conservative calculations regarding effects of pumping. On the other hand, the lowest (Walker and Eakin) coefficient is considered to be unrealistically low for the Lanfair Valley conditions.



LEGEND

MEAN ANNUAL PRECIPITATION

—— 4 —— ISOHYETAL LINE (LINE OF EQUAL PRECIPITATION)

LANFAIR VALLEY STUDY AREA

░ STUDY AREA

▨ RECHARGE ZONE

——·· —— SURFACE WATER DRAINAGE DIVIDE

ISOHYETAL INTERVAL: 2 INCHES

SOURCE: RANTZ 1969
DATA FOR CALIFORNIA ONLY

0 15 30 MILES

SCALE

FIGURE 3.9

MEAN ANNUAL PRECIPITATION

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6. To further evaluate the ground water balance for the entire basin, the Mark Group also estimated the amount of flow which could be continuously moving across the Lanfair Valley, at an 11-mile wide cross-section of the basin approximately through the Grotto Hills. Using aquifer properties determined from field tests and an average ground water gradient of 50 feet/mile, the estimated flow is about 3,000 acre-feet per year. This compares with estimates of potential basin flow of 2,500 to 8,000 acre-feet per year calculated by Environmental Solutions, Inc. for a similar cross-section.

7. Based on the variety of analyses performed, the Mark Group concludes that the estimates show a possible recharge of 2,000 to 5,000 acre-feet per year. The value used for evaluations discussed in this report is 2,000 acre-feet per year, which appears to be conservative. Section 3.5.3 discusses estimates of potential discharge locations from the basin to balance this estimate of recharge.

3.5.2 RECHARGE TO THE WEST WELL FIELD AREA

1. The Mark Group (1988) also used the Maxey-Eakin method to estimate recharge to the portion of the basin upgradient from the proposed West Well Field. Comparison of that recharge, to the volume to be withdrawn, indicates the amount of water which would be "mined" from the aquifer during the life of the proposed project. That deficit can then be used to evaluate potential impacts to other locations in the basin.

2. The recharge estimate for the West Well Field is on the order of 300 to 500 acre-feet per year. For additional analyses in this report, an average value of 400 acre-feet per year is used.

3.5.3 DISCHARGE FROM THE BASIN

1. The potentiometric map shown in Figure 3.8 indicates the following two major zones of ground water discharge from Lanfair Valley:

    - The gradient from the entire southwest portion of the Lanfair Valley is toward the Fenner Valley to the south. Underflow in this direction would be through a combination of water gaps and fractured bedrock.
    - The gradient for the majority of the northeastern portion of the Lanfair Valley appears to be toward the Piute Range, where underflow would occur into the Piute Valley. This zone also includes flow which occurs at Piute Spring.

2. The manner in which the flow is divided between the two discharge zones is primarily dependent upon the recharge area contributing to each. Figure 3.9 shows the two subbasin areas, and identifies the portions having more than eight inches of rainfall, where recharge is expected to occur. The northeast and southwest subbasins include about 57 and 43 percent of the total recharge area, respectively.

3. On the basis that the estimated total basin recharge is 2,000 acre-feet per year, it is reasonable to assume that flows through the northeast and southwest subbasins are at least 1,140 and 860 acre-feet per year. The 1,140 acre-feet per year of flow toward the Piute Range must be discharged from the basin as a combination of underflow to Piute Valley and discharge in the Piute Spring area. The reality of this estimate can be determined by evaluating the potential underflow rate discussed in the following paragraph.

4. Underflow between the Lanfair and Piute Valleys occurs as a result of the water table gradient between the two valleys. The rate of underflow can be estimated using the Darcy equation:

$$Q = kiA$$

where:

- k = hydraulic conductivity or permeability of the volcanic rock, estimated to be on the order of 0.13 to 0.26 feet per day (4.5 to 9.0×10^{-5} cm/sec), based on values measured for similar volcanic rock in the Castle Mountains (Section 3.4.1). The higher value reflects the greater amount of fracturing observed in volcanic rock in the Piute Range.

- i = the ground water gradient between the two valleys, which is estimated to vary from about 0.04 to 0.02 at the north and south ends of the range, respectively. These estimates are based upon: (1) the difference in elevation between the ground water elevation estimated in Lanfair Valley (Figure 3.8) and the alluvium surface in Piute Valley; and (2) the distance between the location where the Lanfair Valley alluvium ends at the west side of the range and the Piute Valley alluvium begins on the east side of the range.

- A = the area of flow through the range, estimated to be about 26 million square feet considering a flow length of 10 miles and a flow height (level of ground water in the Lanfair Valley to valley surface in Piute Valley) which varies from 700 and 300 feet at the north and south ends of the range, respectively.

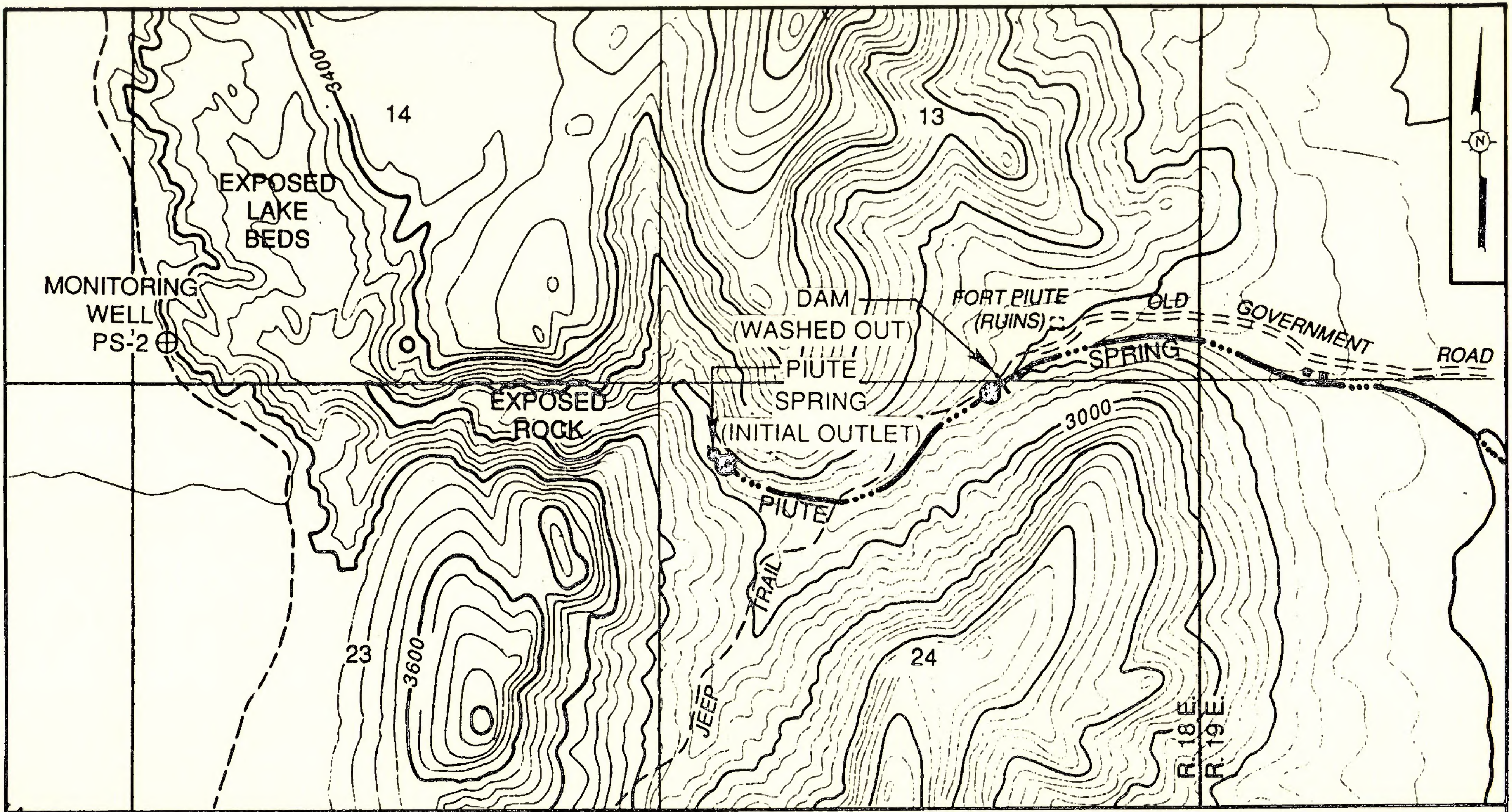
This calculation provides an estimate that underflow to the Piute Valley would be 700 to 1,400 acre-feet per year, including flow at the spring. The above estimate of 1,140 acre-feet per year appears reasonable in comparison with the range of projected flow through the Piute Range. The actual portion of this discharge which occurs as flow at Piute Spring is discussed in the next section.

3.5.4 SPECIAL CONSIDERATIONS AT PIUTE SPRING

1. Discharge at Piute Spring has been monitored monthly at two locations by the Mark Group (1988) since June 20, 1987. One location is 25 feet downstream of the first point of emittance of the spring and the other is 50 feet upstream of a washed out concrete dam which is located approximately 5,000 feet from the first point of emittance. The points of measurement are shown in Figure 3.10. The Mark Group also measures the depth to water in Well PS-2, which is located in Lanfair Valley upgradient of the spring. The results of this monitoring, through November 1988 is as follows:

Date	Flow 25 Feet Below Spring Outlet (gpm)	Flow 50 Upstream of Washed-Out Dam (gpm)	Depth to Water in PS-2 (feet)
06-20-87	41	Not Measured	Not Measured
08-26-87	37	21	431.57
09-28-87	41	37	431.14
11-01-87	45	Not Measured	431.05
11-24-87	45	90	430.79
12-29-87	45	121	430.49
01-28-88	41	121	430.44
02-29-88	45	73	430.21
03-28-88	41	84	430.16
04-29-88	37	84	430.33
05-26-88	45	37	430.33
07-01-88	41	21	434.70
07-28-88	37	37	434.39
08-24-88	41	95	433.95
09-26-88	37	135	432.67
11-04-88	45	114	432.18
11-30-88	45	84	432.15

The larger than normal change in the depth to water at PS-2 which occurred in July 1988 probably is probably related to the Mark Group's attempt to bail the well in order to assess aquifer parameters from well recovery data and collect a water quality sample. Water and drilling mud removed from the 2-inch casing was sufficient to cause a level decrease of about 15 feet. The small diameter of the casing made development difficult and it was decided to leave the well only for observation purposes. The water level had not yet returned to original observation levels by the end of July.



LEGEND

● FLOW MONITORING

⊕ MONITORING WELL

━ • • • ━ PERENNIAL FLOW

SOURCE: 15-MIN. U.S.G.S. TOPOGRAPHIC MAPS OF LANFAIR VALLEY AND HOMER MOUNTAIN QUADRANGLES, SAN BERNARDINO COUNTY, CALIFORNIA, BOTH DATED 1956

0 1400 2800 FEET

SCALE

CONTOUR INTERVAL: 40 FEET

FIGURE 3.10

PIUTE SPRING AREA LOCATIONS OF MONTHLY MONITORING STATIONS

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2. Freiwald (1984) also reported flows, obtained by BLM for the location 50 feet upstream from the washed out dam. These values are:

Date	Estimated Flow 50 Feet Upstream Washed-Out Dam (gpm)
04-15-80	390
09-02-81	62
01-28-82	173

3. The spring flow data indicate a relatively consistent flow of about 40 gpm near the initial point of emittance of Piute Spring, but a highly variable downstream flow condition. The Mark Group has observed that the downstream flow is highest in the winter when evapotranspiration is low, but is lower in the summer when evapotranspiration is the greatest. In order to determine if evapotranspiration could be a viable explanation for this trend, they performed the analysis described below.

4. Evaporation data for Boulder City, Nevada, about 50 miles north of the site, provides the following monthly distribution:

Month	Evaporation (Inches)
January	03.98
February	05.14(1)
March	07.84
April	11.27
May	14.79
June	17.28
July	16.36
August	14.25(1)
September	13.97(1)
October	07.11(1)
November	05.38
December	02.77(1)

These data show a definite seasonal trend, with summer rates exceeding winter rates by a factor of four to five. Boulder City is at an elevation of 2,525 feet and Piute Springs approximately at elevation 2,800 feet. Therefore, this general trend would be expected to be comparable for both locations.

---

(1) Estimated by National Oceanographic and Atmosphere Administration (NOAA).

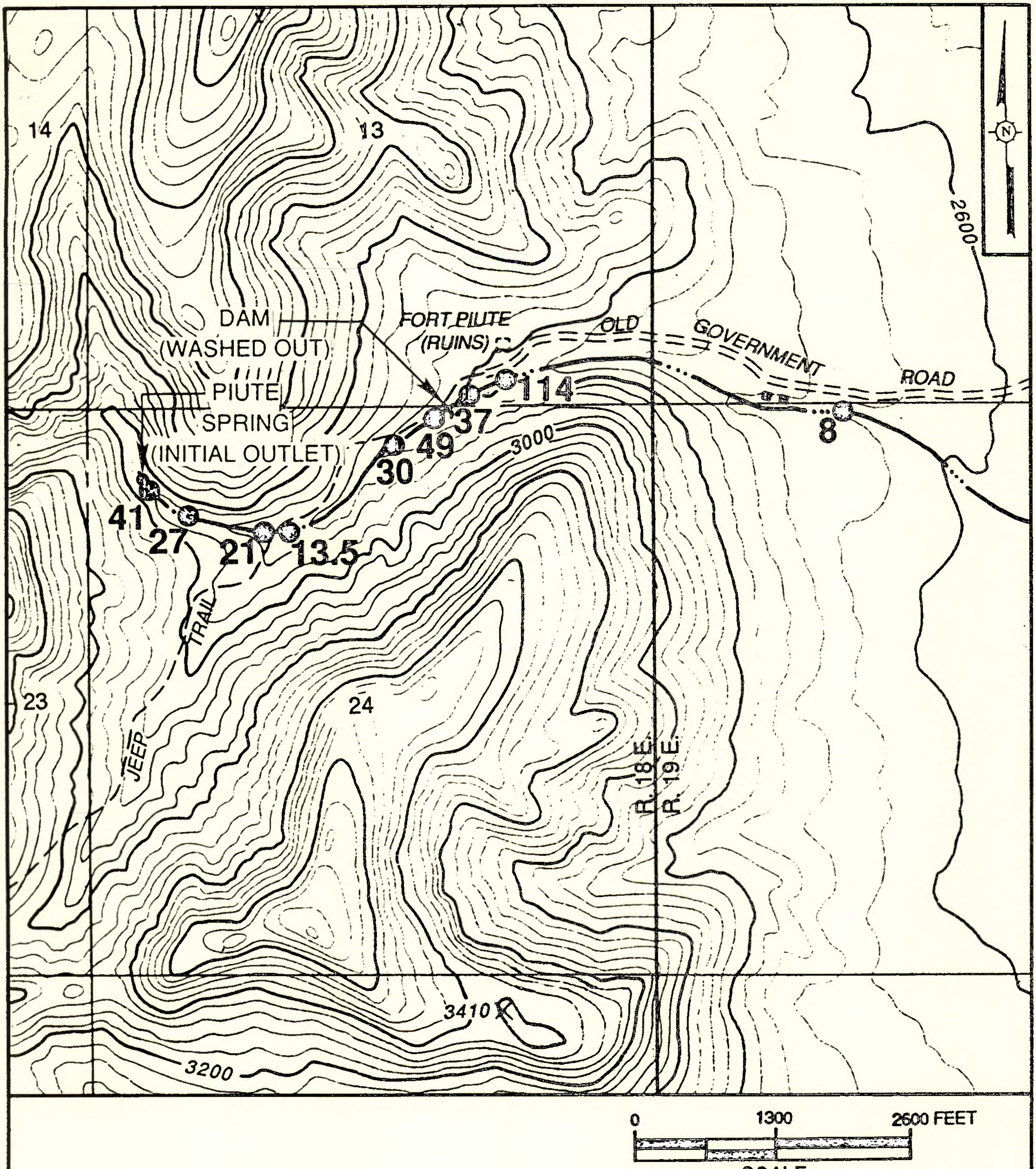
5. Recognizing that an exact prediction of evapotranspiration rate at the Piute Spring area would not be possible with available data, the Mark Group was able to develop some estimated values which indicate that a significant portion of the summer and winter differences in downstream flow can be explained by the evapotranspiration mechanism. The analysis assumed that the rate of evapotranspiration in the heavily vegetated area will be comparable to evaporation from free water for a similar area, based on work by Linsley and Franzini (1979). On the basis of an estimated nine acres of vegetation along the stream, between the two measurement points, the differences in flow between summer and winter conditions is estimated to be about 80 gpm. This compares favorably with the range in measurements which have been observed during the past year.

6. These data and field observations indicate that the spring flow is not occurring at just the first point of emittance. Instead, flow is entering into the spring area at a number of locations, where the eroded Valley intersects fractured zones in the bedrock. To further evaluate these flow conditions, Environmental Solutions, Inc. and the Mark Group measured flows at a variety of locations (Figure 3.11) in June 1988. This data illustrates the anticipated summer trend of flow, decreasing with distance from the first emittance point, although some increase occurred as the abandoned dam location was approached in the downstream direction. Measurements were also taken at three locations downstream from the abandoned dam. These measurements showed an increase in flow (37 to 114 gpm) over a distance of several hundred feet downstream from the abandoned dam, further indicating a condition of additional ground water emittance into the eroded stream valley.

7. The surface flow was observed to diminish downstream from the 114 gpm location as the surface water infiltrated into the Piute Valley alluvium. A lowest reading of 8 gpm was measured about 7,000 feet downstream from the abandoned dam, just before the surface flow disappeared entirely into the subsurface.

8. The following hypothesis is presented as the most likely description of the characteristics of Piute Spring, based upon the data available and detailed field mapping of the area:

    - The basic reason that the perennial flow condition exists is because the canyon has eroded to that depth which results in the land surface intersecting the sloping ground water surface (gradient), which naturally exists between the Lanfair and Piute Valleys along the entire length of the Piute Range. Springs are not evident elsewhere because similar, deep, eroded canyons do not exist.



CONTOUR INTERVAL: 40 FEET

LEGEND

● 37 MEASUREMENT LOCATION AND FLOW (GALLONS PER MINUTE)

—··— PERENNIAL FLOW

SOURCE: 15-MIN. U.S.G.S. TOPOGRAPHIC MAPS OF LANFAIR VALLEY AND HOMER MTN. QUADRANGLES, SAN BERNARDINO COUNTY, CALIFORNIA, BOTH DATED 1956

FIGURE 3.11

PIUTE SPRING MEASURED FLOWS (JUNE 1988)

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- The total flow in the spring area is not the result of a single discharge point, but rather inflow to the eroded channel at numerous locations over a total distance of 5,000 to 6,000 feet.

- The primary origin of the flow is from the upgradient Lanfair Valley. A portion of the flow may occur directly through the fractured zone along the canyon axis. However, a significant portion of flow also occurs along north-south trending faults in the range, which intercept ground water flow from Lanfair Valley and direct it along the path of least resistance (along the faults) to the spring discharge area. The north-south distance of travel along the faults is not known, but it is not likely that the natural gradient between the valleys would be disrupted for more than several thousand feet to either side (north and south) of the gorge.

9. Collectively, these data indicate that the total surface flow into the Piute Spring area probably is on the order of 120 to 150 gpm, or about 200 to 250 acre-feet per year. This would represent about 17 to 22 percent of the 1,140 acre-feet per year of underflow estimated through the entire Piute Range. Considering that underflow through the range occurs over a distance of about 10 miles, the portion directly contributing to the spring would represent a distance of about two miles. These estimates tend to support the water balance data for the entire Lanfair Valley which have been discussed above.

3.6 WATER QUALITY

1. Table D.1 in Appendix D summarizes water quality data available for the Lanfair Valley area as reported by Freiwald (1984), the Mark Group (1988) and SRK (1987). The ground water in the West Well Field and at most other locations in Lanfair Valley is of good quality. A few wells in the western portion of the basin indicate relatively high Total Dissolved Solids values, potentially indicating there is some external influence of those wells as less recharge occurs in that area in comparison with other portions of the basin. That localized condition will not affect the West Well Field area.

2. The Mark Group has reviewed the chemistry data to determine if correlations between waters in different areas could be made, and especially if conditions at Piute Spring could be related to other locations in the basin or recharge areas. Although some similarities and differences can be made, correlations cannot be made.

4.0 WATER SUPPLY REQUIREMENTS

1. In 1987 the initial estimate of water requirements for the proposed project was 1,650 acre-feet per year. Because of concern for the proposed ground water supply and potential related impacts, a variety of conservation measures were incorporated into the project design, thereby reducing the estimated requirement to 1,140 acre-feet per year. In July 1988, the estimated usage was further reduced to an average of about 725 acre-feet per year (450 gpm). This reduction was possible primarily as a result of a new drip irrigation method for applying process solution to heap leach. The method, which has been successful at a number of producing gold mines during the past year, substantially reduces evaporation losses by eliminating most spray applications and related puddling at the surface of the heaps.

2. The current estimate at 450 gpm is projected to supply sufficient water to satisfy the project's entire water needs, including make-up to replace water lost due to evaporation from pads and ponds, moisture retained in the leached ore, dust control on roads, overburden stockpile area and the crushing circuit, as well as domestic needs (i.e., drinking, sanitary facilities, assay laboratory, etc.).

3. Evaluations of potential impacts of pumping ground water for the proposed project discussed in this report are generally based upon extracting the currently estimated 450 gpm rate from the proposed West Well Field. However, because the calculations were being accomplished at various times, while the water requirement estimates were being refined by the project Applicant, the pumping rates assumed in the modeling analyses vary somewhat. For comparison, the pumping rates considered are summarized in Table 4.1, Pumping Rates (gpm).

4. The 900 gpm pumpage rate used to model the unconfined case includes 810 gpm from the West Well Field and 90 gpm (W-25P and 31B) from the East Well Field. These values are larger than the present project requirements and therefore are conservative. Since adequate aquifer behavior was predicted even with the higher rate, additional modeling at lower extraction rates was not conducted.

TABLE 4.1

PUMPING RATES (gpm)

Well Designation (1)	Well Field Modeling (2)		Lanfair Valley Modeling (3)
	Confined Case	Unconfined Case	
W-3P	--	20	--
W-4P	70	113	71.5
W-7P	50	62	32.6
W-11P	40	50	26.1
W-14P	60	170	78.2
W-15P	90	120	78.2
W-18P	73	120	71.5
W-19P	--	20	--
W-24P	60	135	78.2
W-25P	--	20	--
W-31P	--	70	--
TOTAL	443	900	436.3

(1) See Figure 3.7
(2) See Section 5.3
(3) See Section 5.5

5.0 EVALUATION OF POTENTIAL IMPACTS

5.1 INTRODUCTION

1. This chapter describes a series of analyses undertaken to evaluate the potential for the proposed ground water withdrawal to adversely affect Piute Spring, smaller springs in the vicinity, or existing wells in Lanfair Valley. Each of the analyses was performed by Environmental Solutions, Inc., except for detailed ground water flow modeling of the West Well Field area. That evaluation was performed by the Mark Group (1988).

2. The analyses have been performed using site characteristics described in Chapter 3.0 and water requirements described in Chapter 4.0. When available data did not permit the specifications of a single quantitative characteristic, a conservative, but reasonable estimate was used. To that extent, it is believed that the overall evaluation results are conservative.

3. The analyses conducted are discussed in the following sections:

   - Section 5.2: Zone of Influence Estimates - These analyses were conducted to estimate the approximate area which could be affected by the proposed pumping and the order of magnitude of time for the effects to migrate to other locations within the basin.
   - Section 5.3: Computer Modeling of the Well Field Area - This computerized analysis was conducted to evaluate the capacity of the well field to satisfy project requirements and to determine more accurately the cone of depression and zone of influence during the pumping period.
   - Section 5.4: Total Aquifer Drawdown Estimate - This calculation was performed to determine if significant effects could be expected using average effects of the pumping over the entire basin.
   - Section 5.5: Computer Modeling of the Entire Lanfair Valley - This computerized analysis was conducted to determine if the cone of depression caused by pumping would move across the Valley, over the long term, and eventually cause a larger than average water level drop to occur upgradient from Piute Spring.

5.2 ZONE OF INFLUENCE ESTIMATES

1. Initially, several relatively simple calculations were performed to indicate the approximate area within Lanfair Valley which could be directly affected by removal of 450 gpm from the West

Well Field for a 10-year period. These estimates were then used to develop the appropriate configuration of more extensive modeling activities.

2. The zone of influence calculations are discussed in the following sections:

    - Section 5.2.1 - Aquifer Travel Time Evaluation
    - Section 5.2.2 - Limitations Due to Ground Water Gradient
    - Section 5.2.3 - Theis Uniform Aquifer Analyses

5.2.1 AQUIFER TRAVEL TIME EVALUATION

1. The rate (velocity) at which ground water can flow from the West Well Field to the Piute Spring area provides one indicator of the order of magnitude of time that might be required for the proposed pumping to cause an effect, if any, at the spring. This velocity is a function of the hydraulic conductivity (permeability) and effective porosity of the aquifer and the slope or gradient of the ground water surface between the two locations.

2. As discussed in Section 3.2.1, the hydraulic continuity between the well field and the spring may be disrupted by a buried bedrock high zone extending between the Castle Mountains and Hackberry Mountain. In order to be conservative regarding travel times, however, the calculations have considered that aquifer conditions similar to those at the well field are continuous throughout the basin (e.g., there is no buried, high bedrock zone).

3. A range of flow velocities (v) are calculated based on equation: $v = \frac{ki}{\eta}$ and the following data presented in Sections 3.3.5 and 3.4.1:

    - An average gradient (i) of 0.015 (77 feet per mile) between the West Well Field and Piute Spring.

    - Combinations of hydraulic conductivity (k) and effective porosity (η) of:

        - 1.4×10^{-3} cm/sec and 0.15
        - 9.1×10^{-4} cm/sec and 0.15.

4. The estimated flow velocity determined from these aquifer characteristics varies from 60 to 140 feet per year. These velocities indicate a ground water travel time on the order of 600 to 1,400 years along the 16-mile distance between the proposed West Well Field and Piute Spring.

5. The effects of ground water removal, on water levels away from the pumping area, may occur in a shorter period than the time required for simple flow of water to occur between two points. Therefore, these estimates of flow times may not be accurate for predicting the time at which pumping could influence water levels near the spring. However, the comparisons are sufficient to conclude that if a ground water level effect were to occur in the spring area, it would not be observed for many years after pumping for the project had been completed. The more detailed modeling discussed in Section 5.5 accounts for longer term changes.

5.2.2 LIMITATIONS DUE TO GROUND WATER GRADIENT

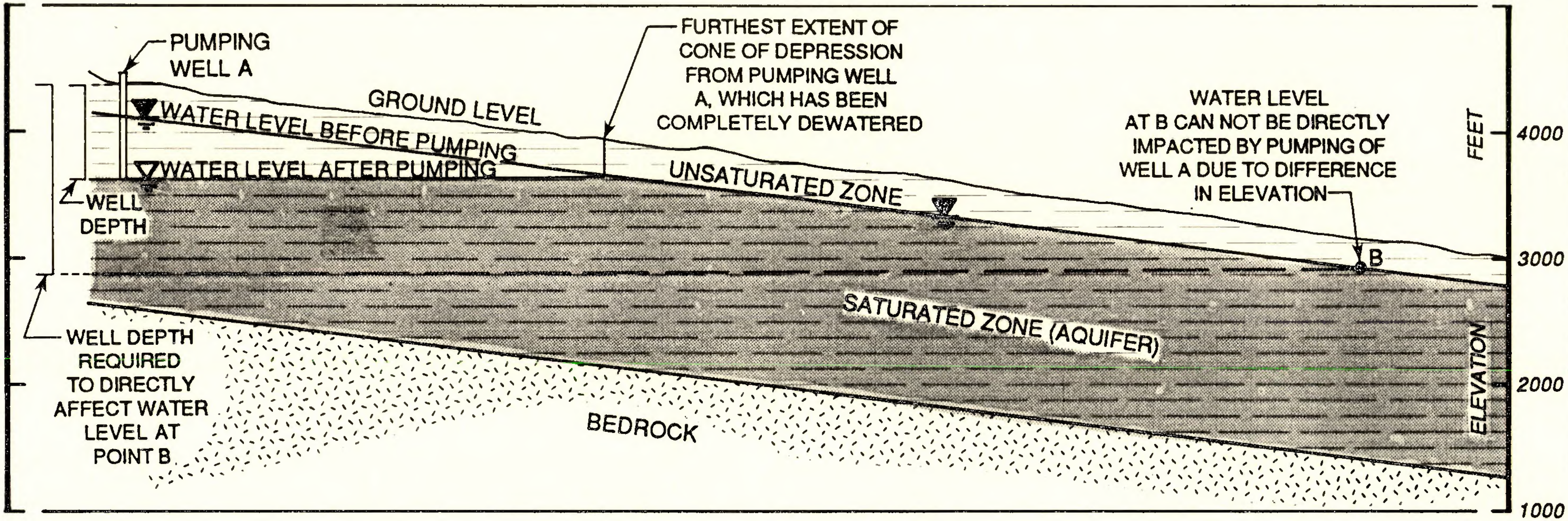
1. Figure 5.1 illustrates why the cone of depression due to pumping from a sloping, unconfined aquifer can extend downgradient only that distance to where the bottom of the pumping wells are at the level of the water table. Beyond that distance, water cannot migrate upgradient toward the well.

2. The wells which have been installed in the West Well Field are drilled to depths of 330 to 483 feet below the water table. Considering that the water table could be drawn down 400 feet and a natural ground water surface gradient of about 0.015 to 0.020, the maximum distance that the cone of depression could extend downgradient would be about four miles. In practice, the feasible distance would be much less because some amount of gradient back toward the well would be required at an equilibrium.

3. Since Piute Spring is about 16 miles from the West Well Field, it is apparent that the spring could not be impacted directly by the pumping cone of depression. This limitation is further discussed in Sections 5.2.3 and 5.3. Sections 5.4 and 5.5 discuss evaluation of potential longer term effects, when the slow downgradient migration of the depressed ground water surface might occur.

5.2.3 THEIS UNIFORM AQUIFER ANALYSES

1. An additional relatively simple procedure for estimating the zone of direct influence from the well field is to calculate the shape of the cone of depression, using the Theis (1935) Method for a non-sloping aquifer with a large lateral extent. This procedure was used to estimate the


PUMPING WELL A
FURTHEST EXTENT OF CONE OF DEPRESSION FROM PUMPING WELL A, WHICH HAS BEEN COMPLETELY DEWATERED
GROUND LEVEL
WATER LEVEL BEFORE PUMPING
WATER LEVEL AFTER PUMPING
WELL DEPTH
UNSATURATED ZONE
WATER LEVEL AT B CAN NOT BE DIRECTLY IMPACTED BY PUMPING OF WELL A DUE TO DIFFERENCE IN ELEVATION
B
SATURATED ZONE (AQUIFER)
WELL DEPTH REQUIRED TO DIRECTLY AFFECT WATER LEVEL AT POINT B
BEDROCK
ELEVATION FEET
4000
3000
2000
1000

LEGEND

▼ WATER LEVEL BEFORE PUMPING

▽ WATER LEVEL AFTER DEWATERING WELL A

FIGURE 5.1

SCHEMATIC DIAGRAM OF PUMPING IMPACT LIMITATIONS

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water table drawdown at two and four miles from a single well pumping 450 gpm, considering aquifer permeability values of 29.1 to 19.4 gpd/ft^2 (1.4 x 10^{-3} and 9.1 x 10^{-4} cm/sec) and aquifer thicknesses of 300 and 600 feet.

2. These calculations indicate an expected drawdown at the well of 59 to 162 feet. At two miles, the drawdown after 10 years would be between 2.0 and 2.5 feet. At four miles from the well, the drawdown would be less than one half foot. These data do not provide any evidence to indicate that influence resulting from pumping in the West Well Field would extend near the Piute Spring area.

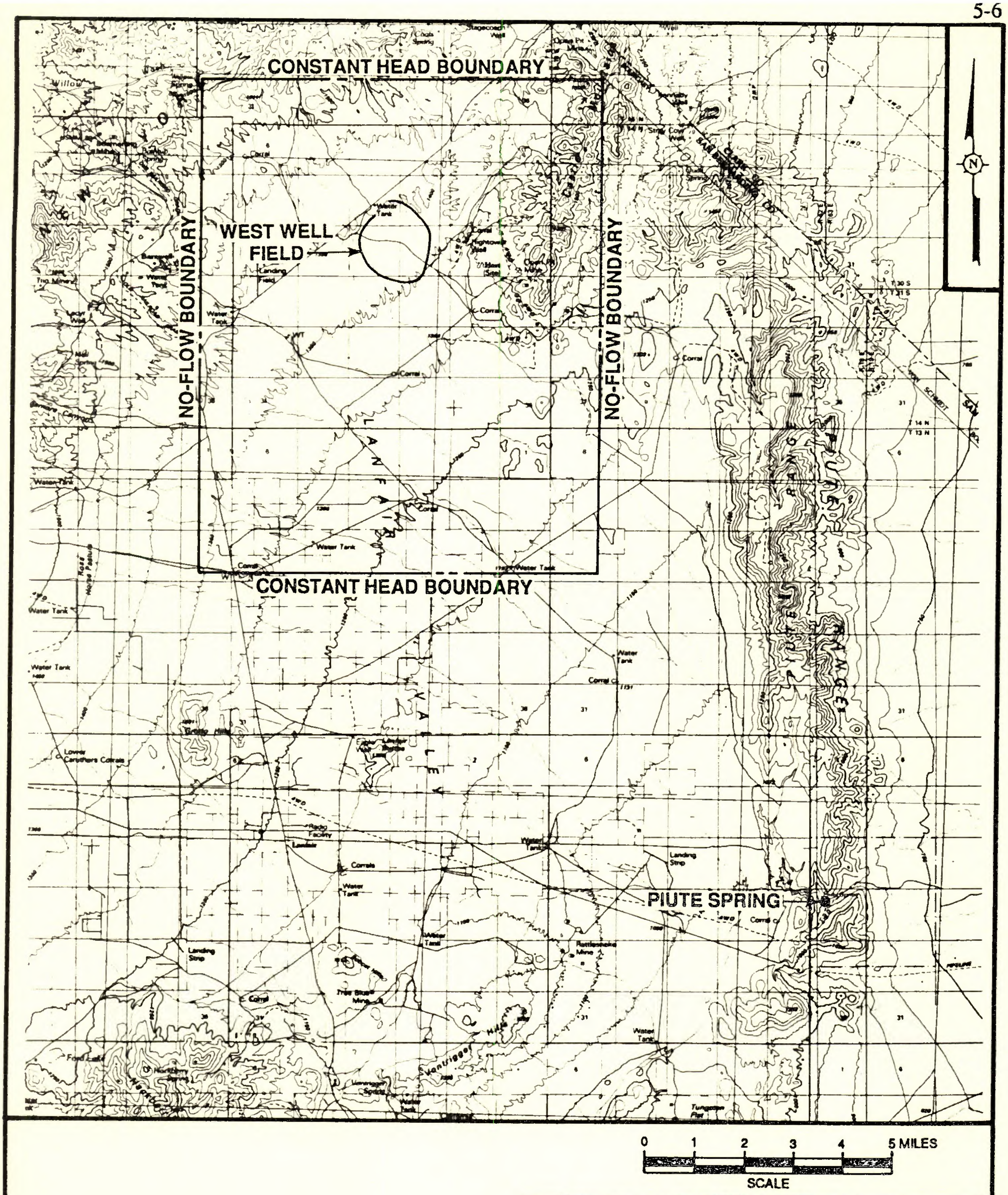
5.3 COMPUTER MODELING OF THE WELL FIELD AREA

1. To more accurately predict the effects of pumping, the Mark Group (1988) conducted computer modeling of the West Well Field for the following purposes:

   - evaluate the viability of the West Well Field as a water supply for the proposed project;
   - assess the effects of continuously pumping 443 gpm for 10 years from the West Well Field;
   - assess the effects of said pumping on the potentiometric gradient toward Piute Spring; and
   - provide recommendations for further exploration, well development, and analysis.

2. Details of the modeling technique are provided in Appendix K of the Mark Group (1988) report. Briefly, the analysis was completed using the Prickett-Lonnquist Aquifer Simulation Model (PLASM) and aquifer data determined from field studies conducted in the Lanfair Valley. An 8- by 10-mile area, shown in Figure 5.2, was selected as the model area.

3. The eastern and western edges of the model were considered to be no-flow boundaries. Such a condition would tend to exaggerate the cone of depression if it were to grow large enough to intersect the boundary. The northern and southern edges of the model were considered to be constant head boundaries with a gradient between them similar to that between the West Well Field and Piute Spring. In effect, this implies that ground water enters from the north and leaves to the south. Recharge expected from the New York Mountains to the west of the well field is not accounted for by the model.



CONTOUR INTERVAL: 50 METERS

BASE MAP: U.S.G.S. 1:100,000 SERIES
TOPOGRAPHIC MAPS OF
DAVIS DAM AND IVANPAH

REFERENCE: THE MARK GROUP
LOCATION MAP, DWG. NO. 4.1

FIGURE 5.2

BOUNDARIES OF WEST WELL FIELD
COMPUTER MODEL

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4. The model was run for two cases: one assuming confined aquifer conditions, and one assuming a water table (unconfined) aquifer. For the confined case, the aquifer would be depleted in the vicinity of the well field in about one year. The Mark Group concludes that the confined condition is not realistic for the aquifer characteristics interpreted from the actual lithologic logs. Appendix K of the Mark Group report (1988) discusses why the unconfined case is appropriate for modeling of the Lanfair Valley conditions.

5. Hydraulic parameters used for modeling of the unconfined case include:

   - Storativity = 0.1.
   - A conservative pumping rate of 900 gpm (compared to the currently projected rate of 450 gpm), distributed among the proposed wells as shown in Table 4.1.
   - Hydraulic conductivities varying between 2.1 x 10^{-3} and 4.7 x 10^{-5} cm/sec (1 and 44 gpm/ft^2). The lowest value is associated with portions of the model which contain volcanic rock.

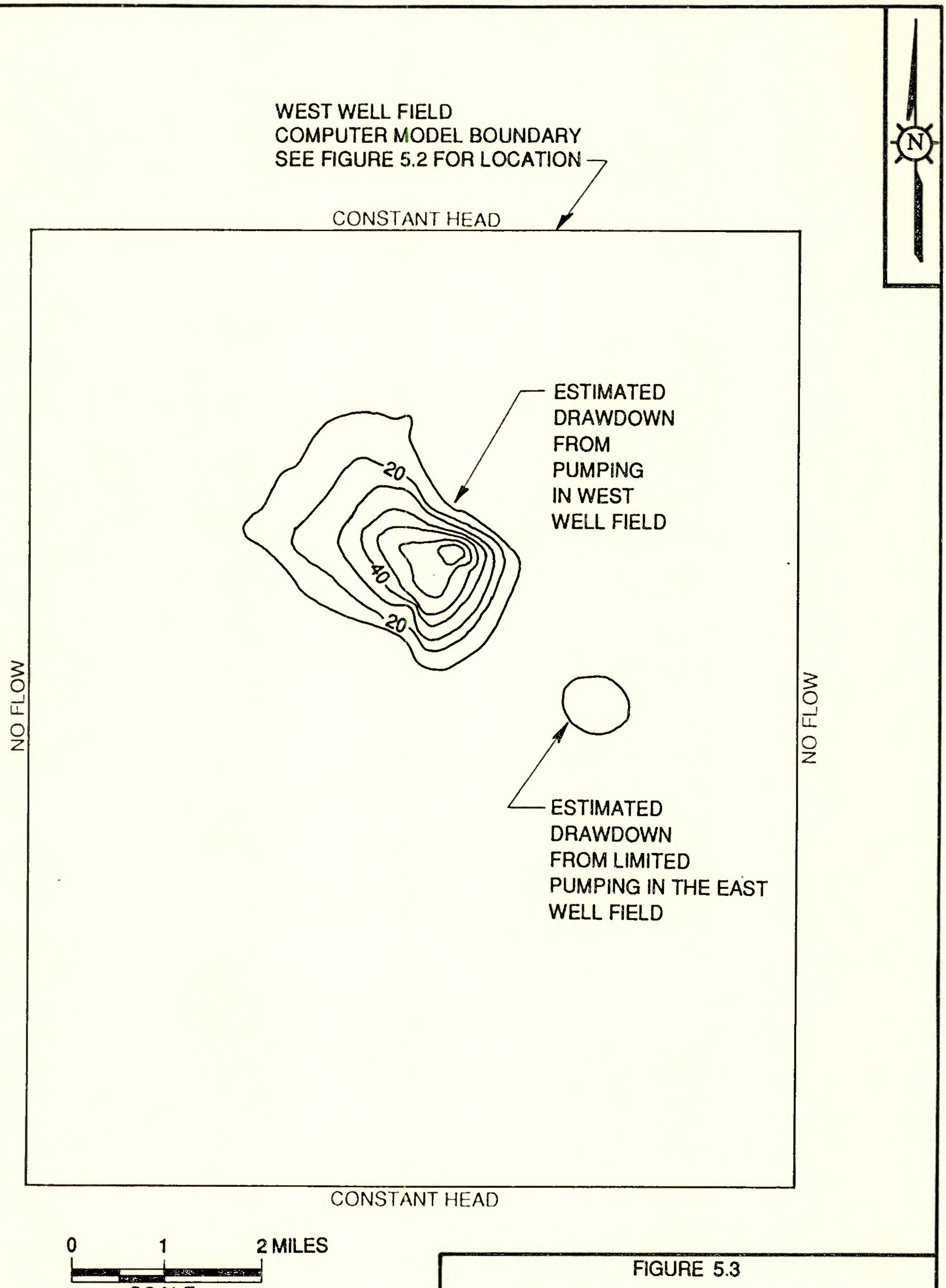
6. Figure 5.3 shows the net change in water level predicted at the end of 10 years of pumping at 900 gpm (810 gpm in the West Well Field). The area which would experience more than 10 feet of drawdown is limited to within two miles of the pumping wells. The overall potentiometric gradient in the basin would not be significantly affected and there is no indication of potential impact on other water wells in the Valley or conditions at Piute Spring.

5.4 TOTAL AQUIFER DRAWDOWN ESTIMATE

1. A preliminary estimate of the potential longer term impacts of the proposed water withdrawal is to assume that:

   - All of the water to be removed (7,250 acre-feet during 10 years) would represent a deficit from the present long-term equilibrium conditions (i.e., recharge equals discharge) of the basin.
   - Over the long period, after the cone of depression had dissipated, this deficit would cause a uniform decrease in the water surface over the entire, approximately 240-square mile northeastern portion of the Lanfair basin.

2. Considering a storativity value of 0.1 for the aquifer, 7,250 acre-feet of deficit would result in a uniform water level drop of about 0.5 feet. Thus, for uniform, long-term drawdown


WEST WELL FIELD
COMPUTER MODEL BOUNDARY
SEE FIGURE 5.2 FOR LOCATION
CONSTANT HEAD
ESTIMATED DRAWDOWN FROM PUMPING IN WEST WELL FIELD
20
40
20
NO FLOW
NO FLOW
ESTIMATED DRAWDOWN FROM LIMITED PUMPING IN THE EAST WELL FIELD
CONSTANT HEAD
N
0
1
2 MILES
SCALE

CONTOUR INTERVAL: 10 FEET

FIGURE 5.3

ESTIMATED DRAWDOWN AFTER PUMPING 10 YEARS FROM WELL FIELD AREA MODEL

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REFERENCE: THE MARK GROUP, 1988
DWG. NO. 4.7

REVISED 3/10/89

conditions, the decrease in water level in Lanfair Valley, upgradient from Piute Spring, would be about 0.5 feet in comparison with the existing water level difference of about 80 feet between the valley aquifer and the spring (as measured at PS-2 and PS-3).

3. A lowering of the ground water level of this extent would decrease the gradient between the Valley and spring by less than one percent and could reduce the flow by about that same percentage. This would amount to a change of less than 0.5 gpm at the first point of emittance and about 1 gpm for the entire spring area. These changes are much less than the natural flow variations which have been observed, and it is concluded that an average water level decrease of this magnitude would not noticeably affect conditions at the spring.

5.5 COMPUTER MODELING OF THE ENTIRE LANFAIR VALLEY

1. Each of the analyses discussed above indicate that extracting water at the West Well Field would not have a noticeable effect on flow conditions at Piute Spring. The only physical factor which those calculations do not consider is the possibility that the cone of depression caused by 10 years of pumping could migrate across the basin and eventually cause a larger decrease in the ground water level surface. To quantify this potential impact, the longer term fate of the cone of depression was evaluated using the modeling technique discussed in this section.

2. The computer code selected for this model is the McDonald and Harbaugh (1984) three-dimensional flow model developed for the USGS. This code was selected because:

   - The model can account for a range of aquifer properties, which can vary both laterally and vertically.
   - Data input is flexible and easily modified to suit anticipated aquifer conditions.
   - The code provides flexibility for evaluating boundary discharge conditions, allowing the most realistic assumptions for the Lanfair Valley and Piute Spring areas to be considered.
   - The technique is a widely accepted, verified modeling code which is available for personal computer applications.

3. This model also predicts the drawdown configuration in the vicinity of the well field. However, because its primary purpose is to evaluate the entire basin conditions, the predicted well field conditions discussed in Section 5.3 should be considered as most accurate for that limited, localized area.

4. Application of the McDonald and Harbaugh model to the Lanfair Valley and proposed project pumping condition is described in the following sections:

   - Section 5.5.1: Size and Shape of the Aquifer
   - Section 5.5.2: Recharge and Discharge Conditions
   - Section 5.5.3: Aquifer Properties and Model Calibration
   - Section 5.5.4: Modeling Results

5.5.1 SIZE AND SHAPE OF THE AQUIFER

1. Figure 5.4 shows the limits of the drainage basin as modeled and the configuration of the finite difference model. The model encompasses the entire alluvial portion of Lanfair Valley as bounded by the surrounding bedrock hills and mountains or water gaps to adjacent valleys. Both the northeastern portion of the basin, where flow is expected to be toward the Piute Range, and the southwestern portion, where flow is expected toward Fenner Valley, are included.

2. Aquifer characteristic data input to the model involves a process known as discretization whereby the aquifer is divided into prisms of porous material called cells within which hydraulic properties are constant so that a single value for each property can represent the entire cell. A single value for each key data element, such as aquifer properties and recharge/ discharge amounts is assigned for each cell. The grid of cells used for this model is shown in Figure 5.4 and was developed to cover the entire area of interest. The spacing of the cell grid was based on multiples of 1/8 mile (the largest cells being 5/8 mile or 3,300 feet), with a finer grid spacing in the area of the West Well Field.

3. Parameters for each cell were determined by overlying the grid on contour maps for each input factor. The parameters were then hand digitized and entered into a data file in the format prescribed for the McDonald and Harbaugh model.

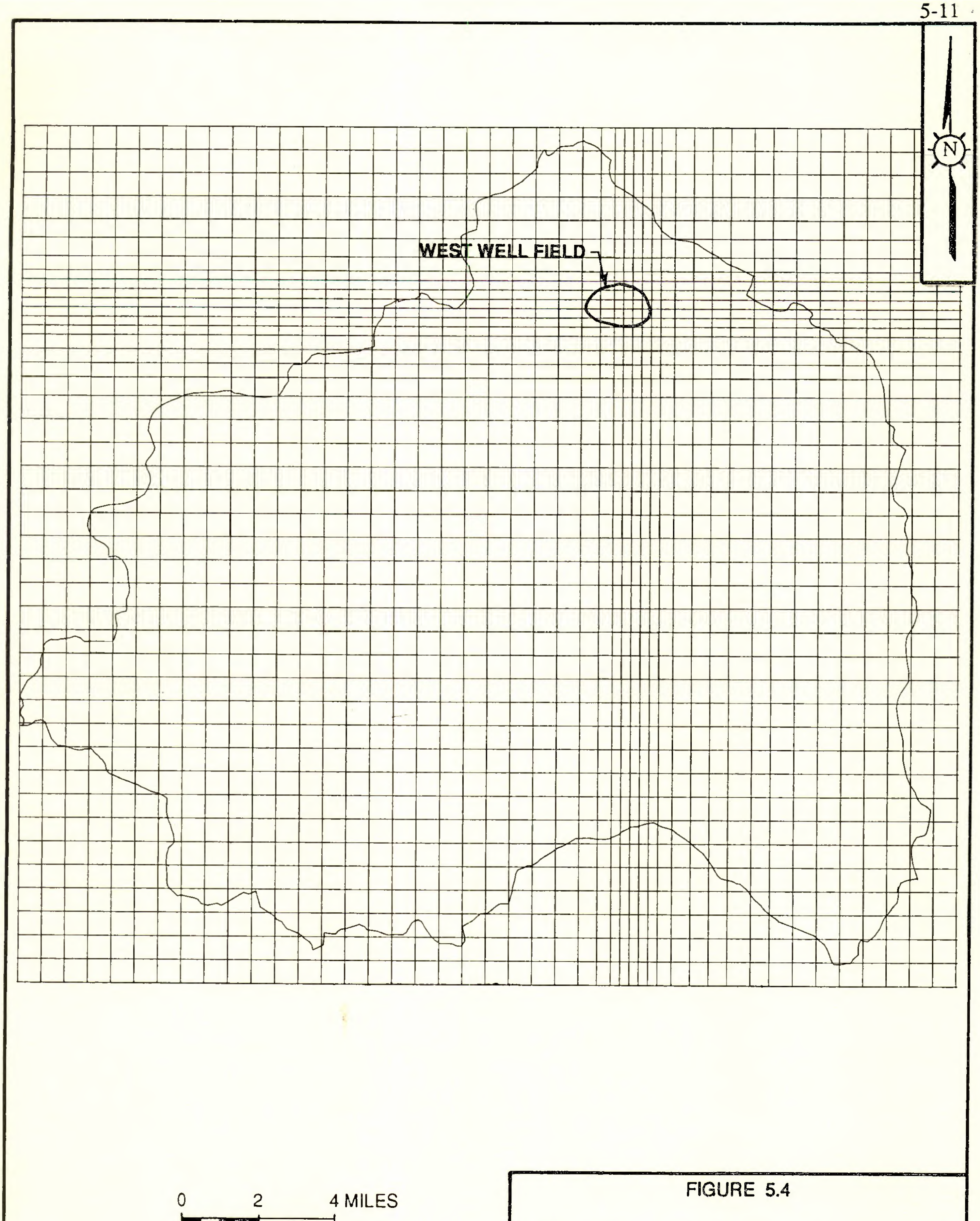

FIGURE 5.4

LANFAIR VALLEY STUDY AREA OUTLINE WITH MODELING GRID

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4. The thickness of saturated alluvium considered in the model is shown in Figure 5.5. Saturated alluvium in the West Well Field area is modeled as being about 600 feet deep, and the thickness increases to 700 feet toward the southeast and southwest basin discharge areas. As discussed in Section 3.2.1, the thickness in the southeast direction is anticipated to be substantially greater because this is the down slope direction of the original valley, before the Piute Range was uplifted. This condition was factored into the model during calibration (Section 5.5.3) by varying transmissivity in the southeast direction as required to:

   - have the existing basin gradients be compatible with equilibrium inflow/outflow conditions;
   - provide a flow pathway which emphasizes the potential for the Piute Springs area to be a main discharge location for Lanfair Valley ground water.

5.5.2 RECHARGE AND DISCHARGE CONDITIONS

1. The amount of recharge used for the model is 2,000 acre-feet per year for the entire Lanfair Valley. This is the lower and more conservative value of the 2,000 to 5,000 acre-feet per year estimate discussed in Section 3.5. The portions of this recharge flowing toward the Piute Range and Fenner Valley are not specified as input to the model. Instead, those values are calculated automatically as part of the modeling process.

2. Distribution of the 2,000 acre-feet per year of recharge is illustrated in Figure 5.6. The location of recharge is based on the following assumptions:

   - No significant recharge occurs on high mountain slope areas because of the low rock permeability and rapid runoff rates.
   - Maximum infiltration occurs in the coarser grained alluvium found at the base of the mountains. An infiltration value of three percent of precipitation was used for these areas, the location and shape of which were determined by topography and land form.
   - The amount of infiltration then reduces with decreasing topography until no recharge occurs in the lower elevation portions of the basin.

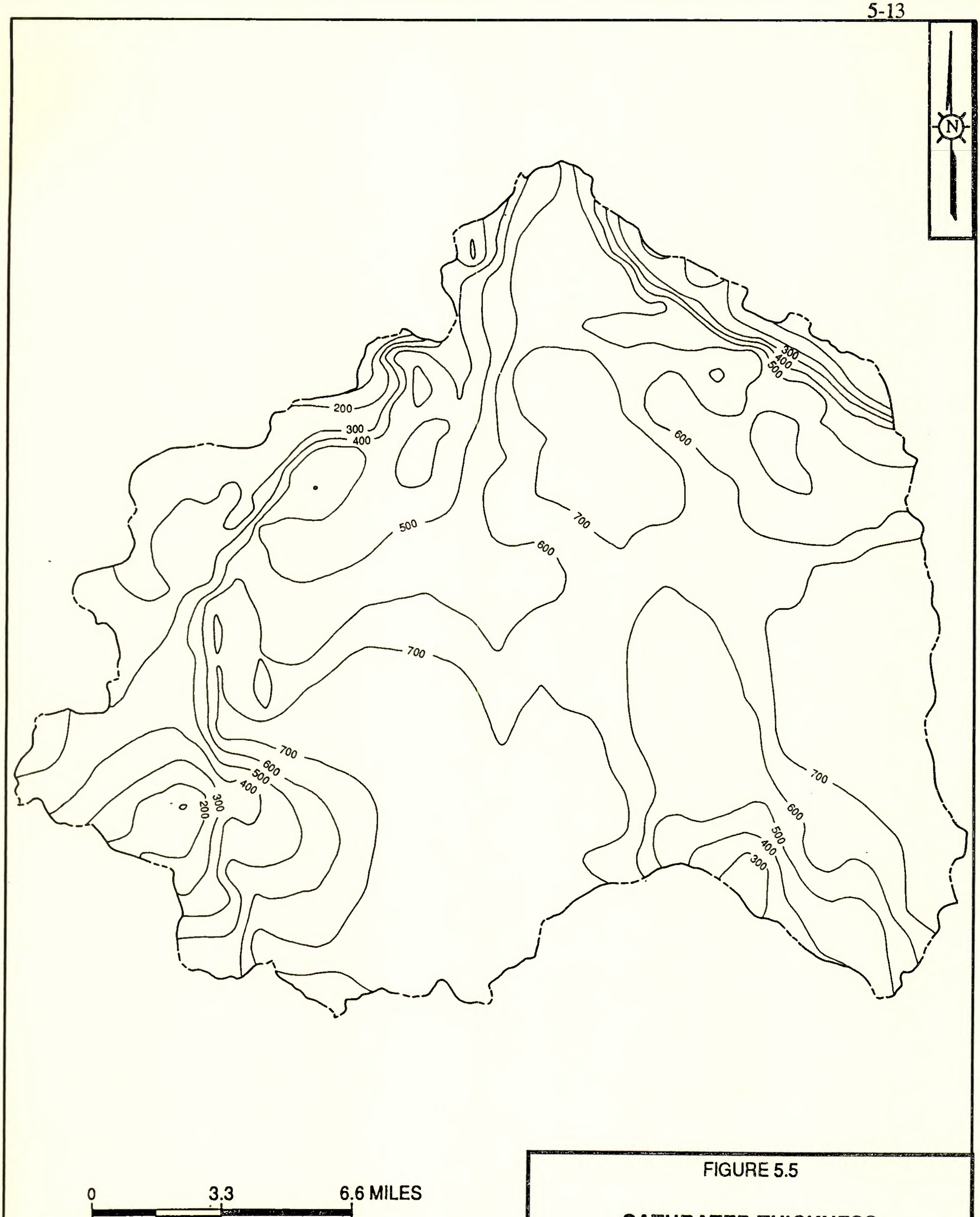

FIGURE 5.5

SATURATED THICKNESS (IN FEET)

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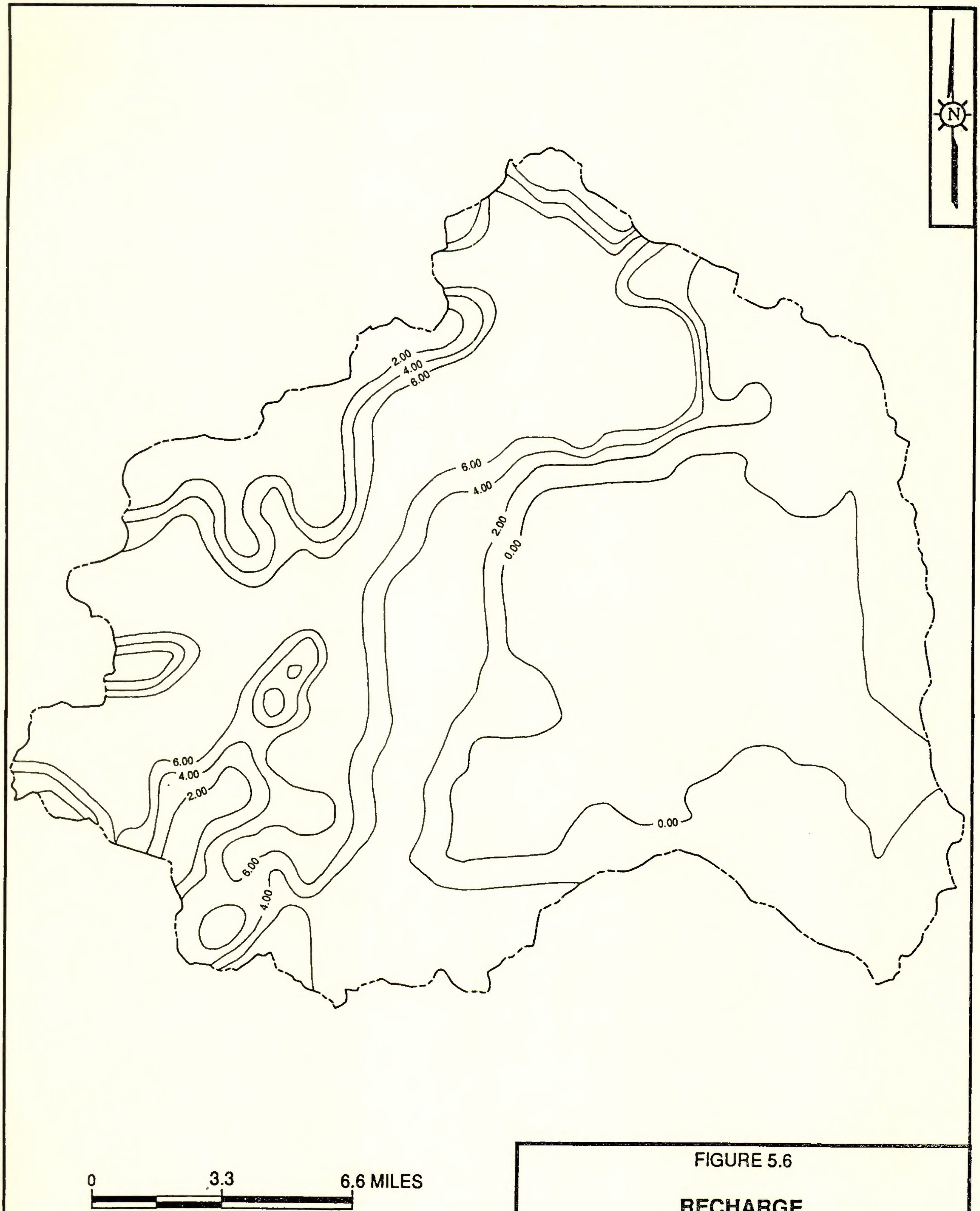

FIGURE 5.6

RECHARGE
(10^{-5} FT/DAY)

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3. Discharge amounts and locations are not assigned to the model, but instead are calculated based on the aquifer and boundary conditions. Discharge locations allowed for in the model include:

   - A 5-mile distance along the Piute Range, extending four miles north and one mile south of Piute Spring.

   - Several locations along the southern boundary including the Sacramento, Woods, and Watson Washes (see Figure 1.2).

   Each potential discharge location was modeled so that the amount of discharge is dependent upon the water surface elevation in the Lanfair Valley, and the resulting gradient to the adjacent area. This most closely simulates natural underflow conditions between basins.

4. During calibration, as discussed below, most effort was directed toward obtaining compatibility of gradients and water level equilibrium along the important Piute Range discharge location. Strict calibration of the model for flow toward the south was not attempted because that is not the area of concern.

5.5.3 AQUIFER PROPERTIES AND MODEL CALIBRATION

1. The initial hydraulic conductivities used in the model elements were:

   - 3.5 to 6.1 x 10^{-4} cm/sec (7.4 to 13 gpd/ft^2) for alluvium.
   - 7 x 10^{-5} cm/sec (1.5 gpd/ft^2) for the volcanic rock.

   These values were selected based upon transmissivities calculated from the 72-hour aquifer test and estimates of the saturated thickness discussed in Section 3.4.1.

2. The storativity values used are based on the aquifer being an unconfined system for long-term conditions. A small amount of confinement, to account for the comparison of static water level and the first indication of water during drilling discussed in Section 3.3.4.1, was built into the model. This limited amount of confinement is incorporated into the model by assigning a storage coefficient of 0.0001 for the top 65 feet of alluvium and a value of 0.1 for the underlying material.

3. The model was calibrated by systematically modifying the permeability parameter during an iterative process directed toward simulating a steady state condition, prior to initiating

pumping. The steady state simulation was considered to be successful when the general potentiometric surface approximated the conditions estimated from existing well data (Figure 3.8) and the amounts of water entering and leaving the system were approximately equal. For purposes of this evaluation, a conservative balance was established by forcing a large portion of the discharge to occur in the Piute Spring area. This establishes the basin subsurface configuration which maximizes the potential for an impact at the spring to be predicted as a result of pumping in the West Well Field.

4. The process of fitting the model to the potentiometric surface trend was accomplished primarily by modifying hydraulic conductivity. This could also have been accomplished by changing the aquifer thickness or a combination of these two procedures. In order to develop the break in slope of the gradient (steeper to shallower) which occurs for the flow direction toward the Piute Range (Figure 3.8), and to have the portion of the range in the vicinity of the spring be a major basin discharge location, it was necessary to increase the hydraulic conductivity in the southeast direction. This is reflected by the final transmissivity distribution indicated in Figure 5.7. This calibration indicates that in order for a major portion of the Lanfair Valley ground water discharge to occur along the Piute Range (near Piute Spring) a combination of hydraulic conductivity increase or aquifer thickening must occur in the southeast direction. Geologically, this indicates that in order for the proposed well field and spring area to have the greatest potential to be hydraulically connected, the sandy and gravelly alluvium underlying lake bed deposits in the vicinity of the range must be deep and/or relatively permeable. The model results discussed below are based on this conservative assumption.

5.5.4 MODELING RESULTS

1. Application of the calibrated model consisted of the following steps:

    - A 27.4-year no stress period was included at the start of the model to obtain a steady state condition.
    - The wells listed in Table 4.1 were then pumped continuously at a combined rate of 436.3 gpm for a 10-year period to determine the entire cone of depression.
    - The simulation was continued for a period of 1,000 years beyond pumping to determine how the cone of depression would migrate across the basin and to determine long-term flow conditions at the Piute Range.

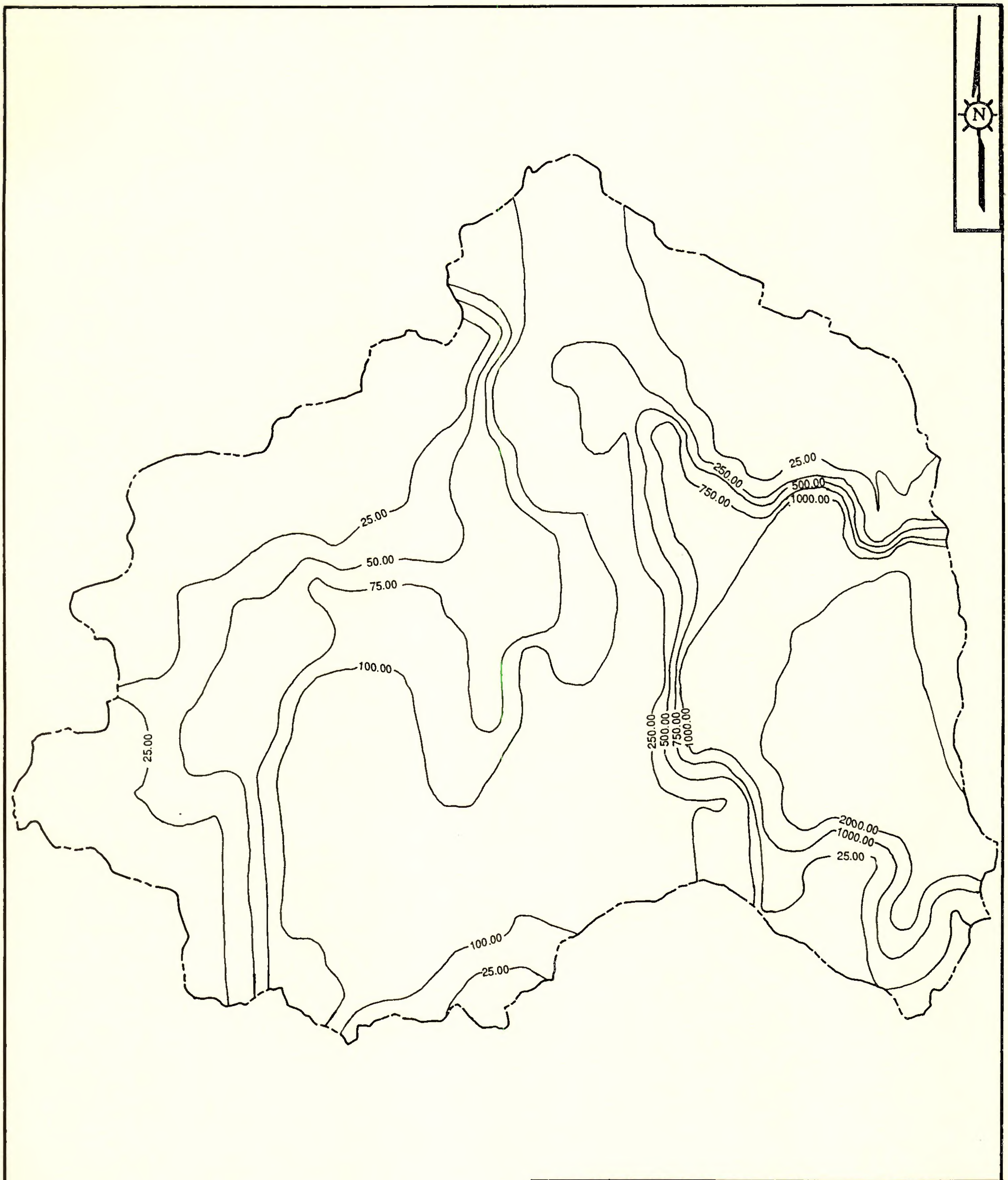

FIGURE 5.7

TRANSMISSIVITY
(FT^2/DAY)

CASTLE MOUNTAIN PROJECT

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2. Figure 5.8 shows the cone of depression after 1 and 10 years of pumping, and 1, 7, and 30 years after the pumping is stopped. These data show the following:

   - During pumping, the cone of depression is limited to a radius of about six miles from the well field. This zone is somewhat larger than that predicted for the PLASM model (Section 5.3) probably because of the conservative semi-confined aquifer assumption and the calibrated values for hydraulic conductivity (transmissivity). The drawdown condition does not approach the Piute Spring area during the pumping period.
   - The size of the cone of depression begins to dissipate after pumping is completed due to natural recharge. The depressed zone is nearly gone in seven years and is completely gone within 30 years.
   - During the term that the cone of depression is being dissipated, it does not migrate measurably toward the Piute Range and therefore a large water level decrease near to Piute Spring would not occur.

3. Discharge from the basin as underflow to the Piute Valley is estimated to be about 1,320 acre-feet per year. The remaining 680 acre-feet would discharge directly into Fenner Valley. These values compare favorably with the 1,140- and 860-acre-feet per year estimates determined by the water balance evaluations discussed in Section 3.5. This comparison indicates that the general division of ground water flows toward the two directions, based on the estimated potentiometric surface in the Valley, is reasonable.

4. The final evaluation determined from the model relates directly to potential long-term flow impacts at Piute Spring. It is not possible to simply compare underflow rates to the Piute Range for a long period after pumping because some variations in flow occur simply because of model stability. This stability factor can be eliminated however, by calculating discharge for the same periods for runs with and without any pumping. This comparison is shown in Table 5.1 for a 1,000-year period after pumping and shows the discharge to be identical for each time increment. These data further confirm that underflow through the Piute Range and at Piute Spring would not be affected by the proposed pumping.

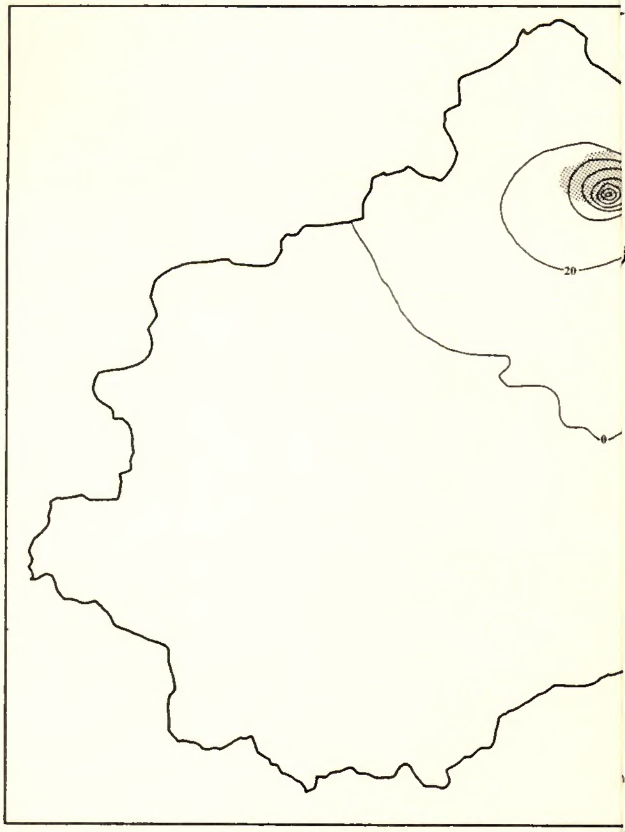
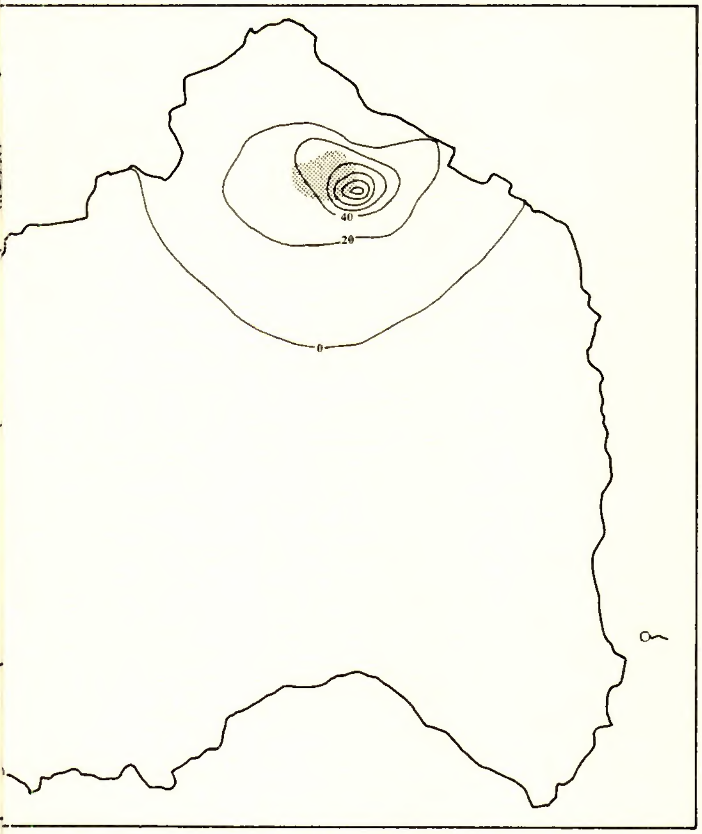


PLATE I: ONE YEAR AFTER PROJECT INITIATIO



FOLLOWING PROJECT COMPLETION

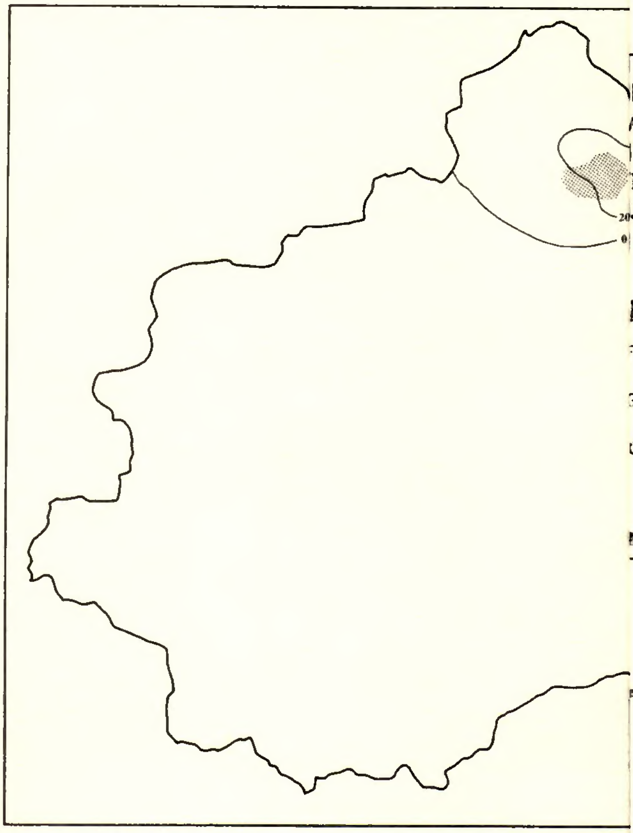


PLATE 4: SEVEN YEARS FOLLOWING PROJECT (

T THE PREDICTED DISTRIBUTION AND LEVEL OF
LD OCCUR FROM PUMPING 450 gpm ANNUALLY FROM THE
A PERIOD OF 10 YEARS. THE DRAWDOWN CONTOURS
NED USING A U.S. GEOLOGICAL SURVEY COMPUTER
THE MAXIMUM GROUND WATER PUMPING IMPACT AREA
ME REQUIRED FOR RECHARGE TO DISSIPATE THE CONE OF
DRAWDOWN IS SHOWN IN 20-FOOT CONTOUR INTERVALS.

ID

FIELD

G

CONTOUR (FEET)

8 MILES

FIGURE 5.8

LANFAIR VALLEY DRAWDOWN (IN FEET)

CASTLE MOUNTAIN PROJECT

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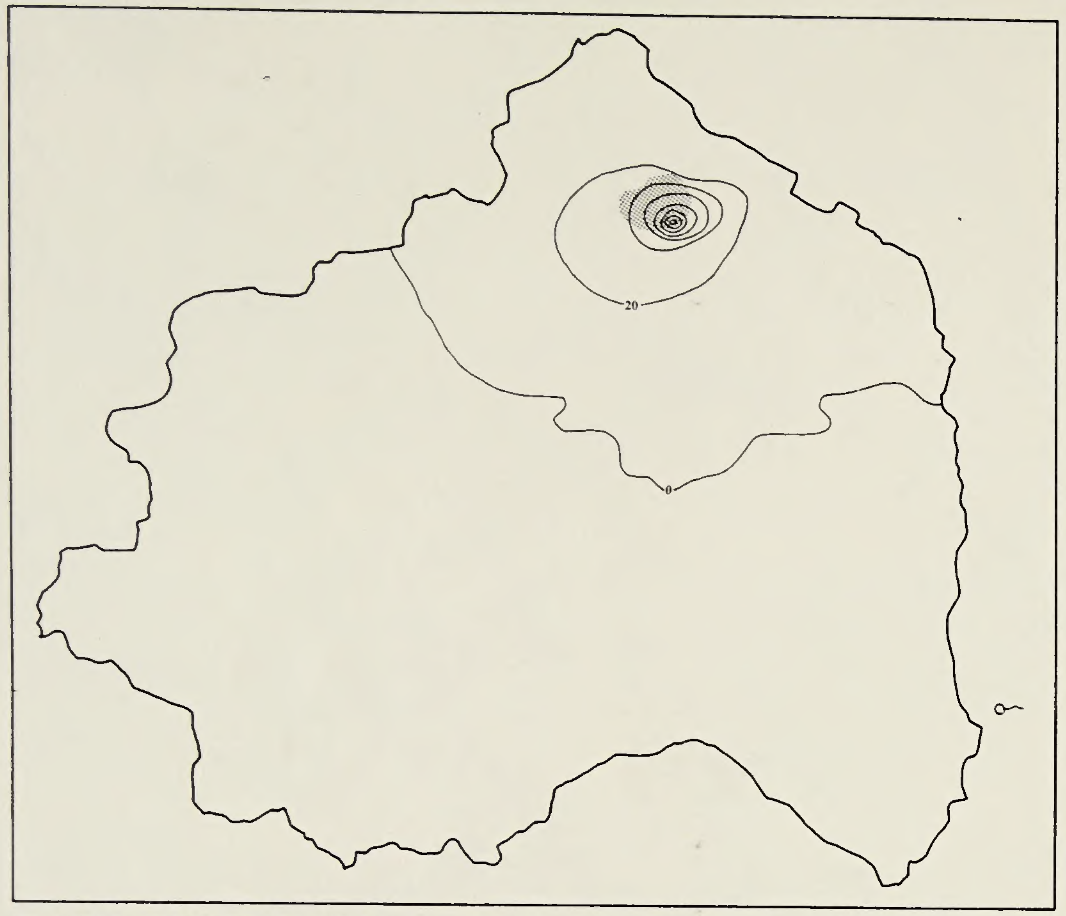

PLATE I: ONE YEAR AFTER PROJECT INITIATION

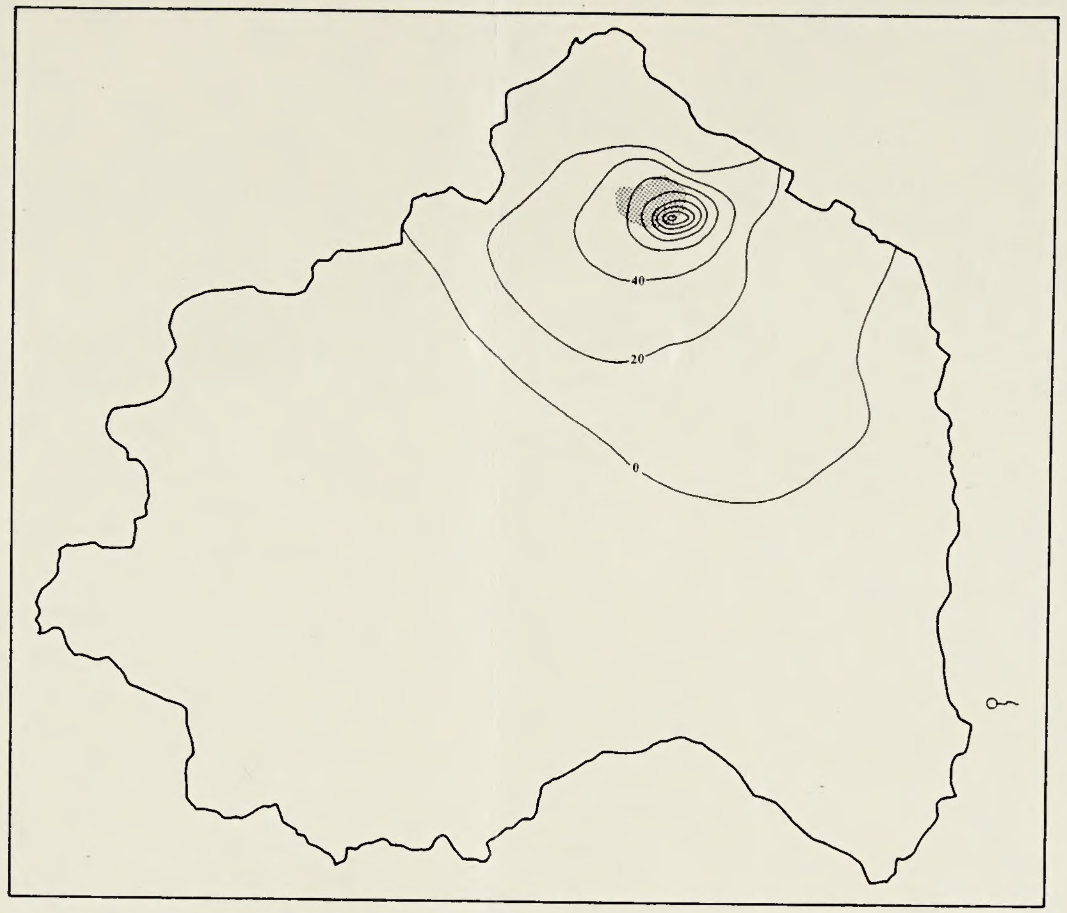

PLATE 2: AFTER TEN YEARS OF PUMPING

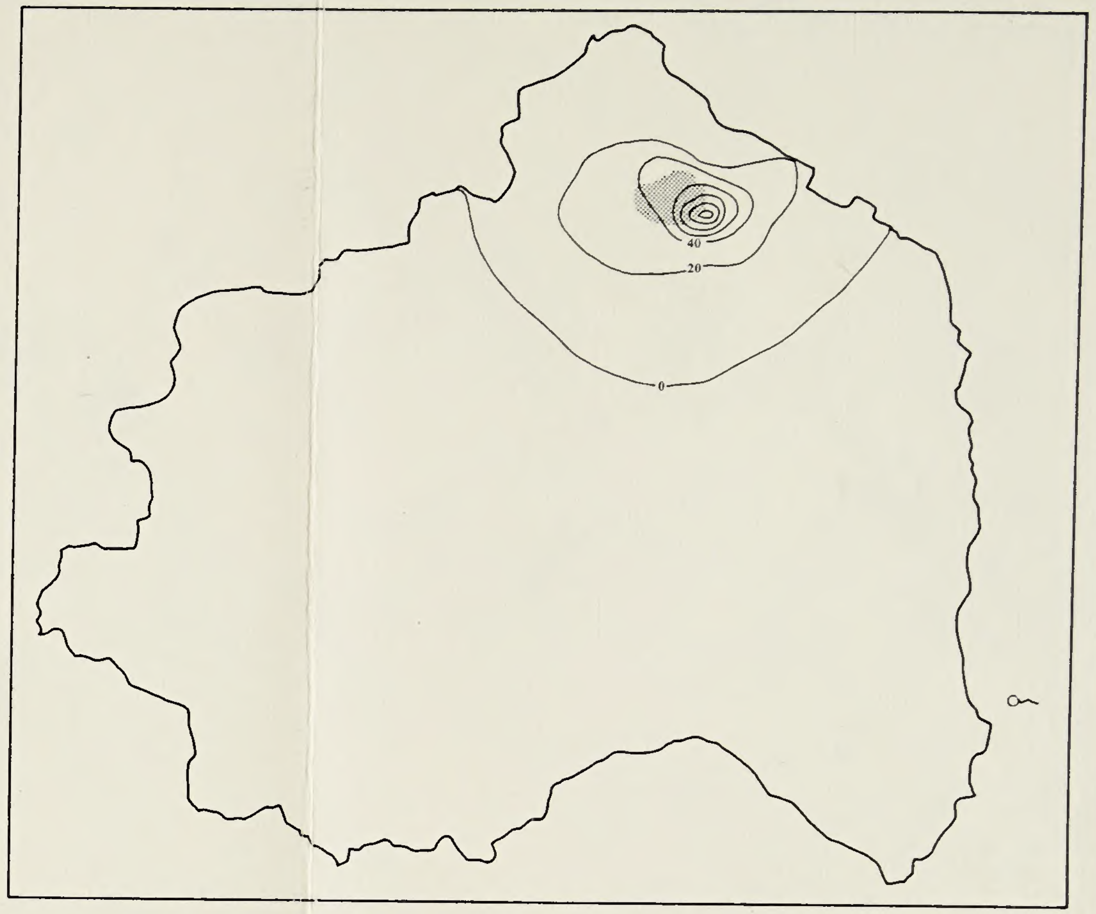

PLATE 3: ONE YEAR FOLLOWING PROJECT COMPLETION

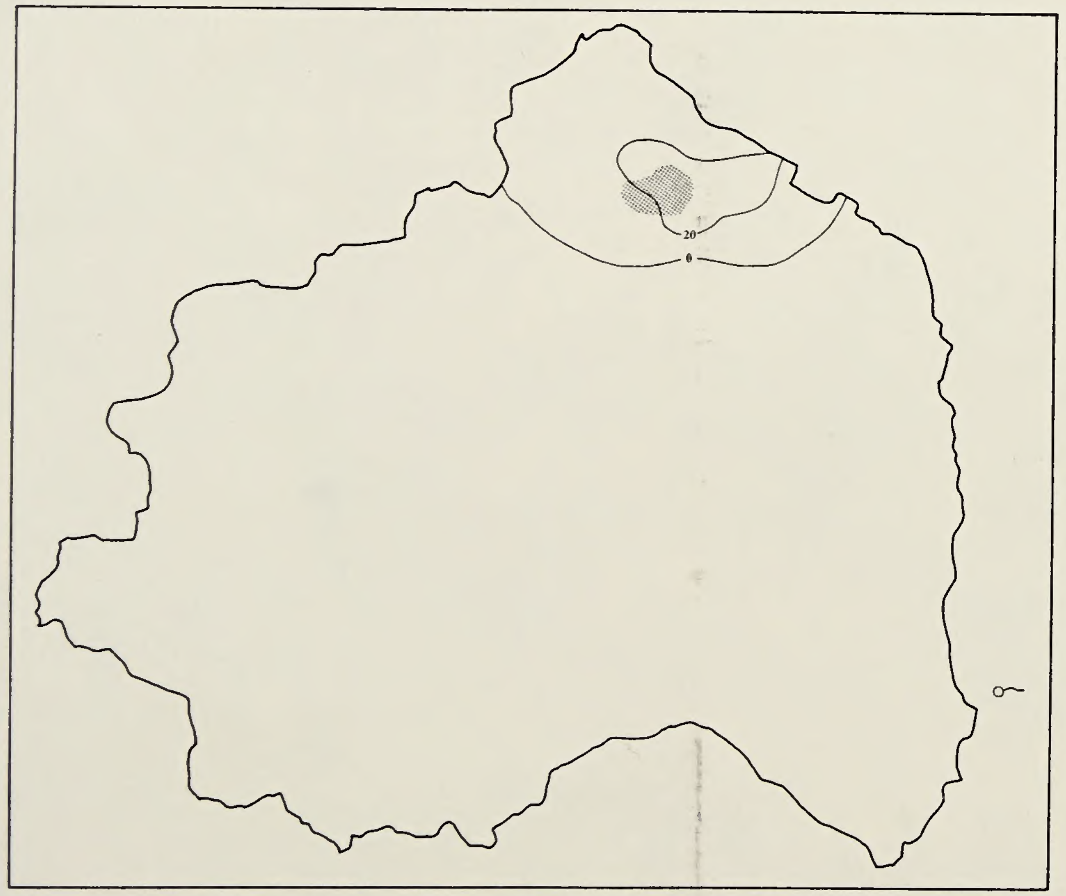

PLATE 4: SEVEN YEARS FOLLOWING PROJECT COMPLETION

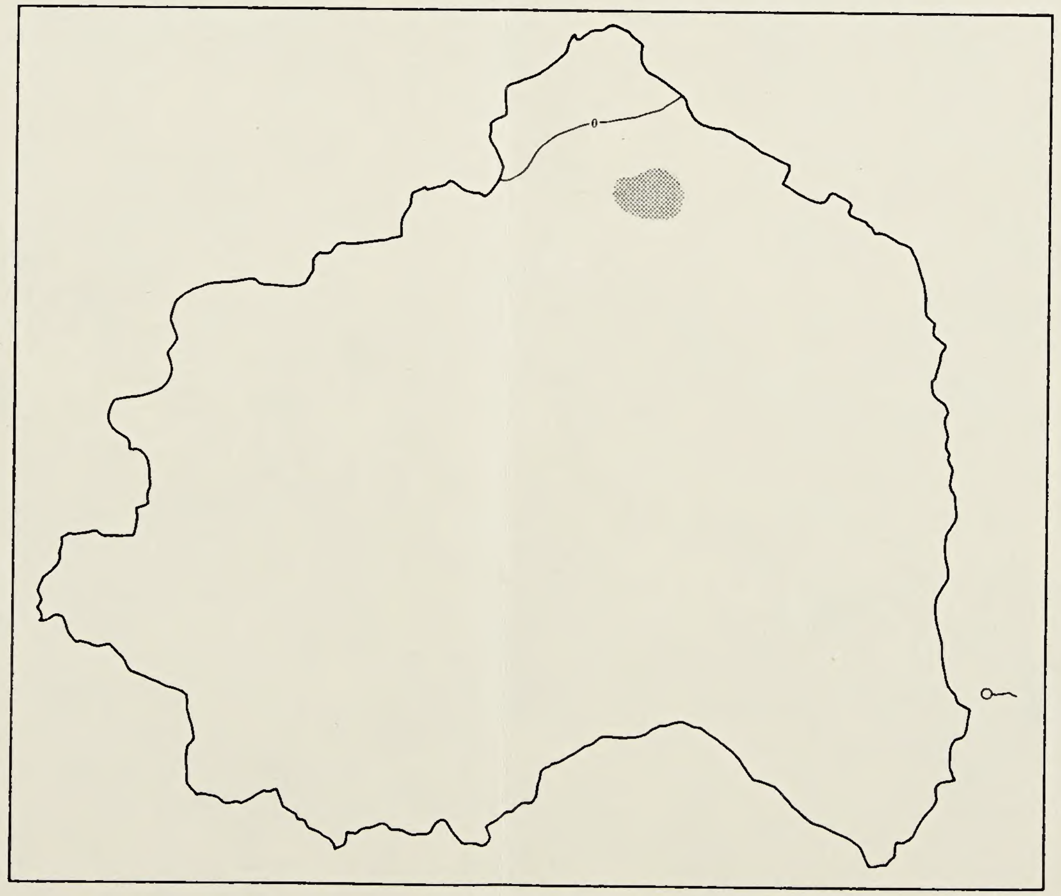

PLATE 5: THIRTY YEARS FOLLOWING PROJECT COMPLETION

EXPLANATION:
THESE FIGURES DEPICT THE PREDICTED DISTRIBUTION AND LEVEL OF DRAWDOWN THAT WOULD OCCUR FROM PUMPING 450 gpm ANNUALLY FROM THE WEST WELL FIELD FOR A PERIOD OF 10 YEARS. THE DRAWDOWN CONTOURS SHOWN WERE DETERMINED USING A U.S. GEOLOGICAL SURVEY COMPUTER MODEL TO CALCULATE THE MAXIMUM GROUND WATER PUMPING IMPACT AREA AND THE LENGTH OF TIME REQUIRED FOR RECHARGE TO DISSIPATE THE CONE OF DEPRESSION. AQUIFER DRAWDOWN IS SHOWN IN 20-FOOT CONTOUR INTERVALS.

LEGEND

▨	WEST WELL FIELD
o~	PIUTE SPRING
—20—	DRAWDOWN CONTOUR (FEET)

0 4 8 MILES
SCALE

N

FIGURE 5.8

LANFAIR VALLEY DRAWDOWN (IN FEET)

CASTLE MOUNTAIN PROJECT
ENVIRONMENTAL SOLUTIONS, INC.

TABLE 5.1

MODELED DISCHARGE THROUGH THE PIUTE RANGE

SIMULATION TIME (YEARS)	DISCHARGE WITH PUMPING (Acre-Feet Per Year)	DISCHARGE WITHOUT PUMPING (Acre-Feet Per Year)
27	1,321	1,321
28	1,319	1,319
29	1,319	1,319
30	1,318	1,318
31	1,318	1,318
32	1,318	1,318
33	1,319	1,319
34	1,320	1,320
35	1,320	1,320
36	1,321	1,321
37	1,322	1,322
38	1,323	1,323
40	1,327	1,327
44	1,337	1,337
52	1,347	1,347
67	1,361	1,361
98	1,370	1,370
161	1,376	1,376
286	1,380	1,380
536	1,381	1,381
1036 (Approximately 1,000 years after the pumping period)	1,381	1,381

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APPENDIX B

WELL, LITHOLOGIC LOG, AND SPRING INVENTORY DATA

TABLE B.1 - WELL INVENTORY

Well Identification	Total Depth (Ft)	Depth to Water (Ft)	Surface Elevation (Ft)	Elevation of static water level(g) (Ft)	Date Water Level Measured	Source	Location				Date Drilled
							Twp	Rng	Sec	Qtr	
11N/14E-2B1	38	12	4840	4828	8/13/81	Freiwald	11N	14E	02	NE	NA
11N/15E-6C1	175	42	4860	4818	8/18/81	Freiwald	11N	15E	06	NW	NA
11N/15E-6J1	143	99	4560	4461	8/18/81	Freiwald	11N	15E	06	SE	NA
11N/15E-8K1	605	510	4280	3770	5/14/71	Freiwald	11N	15E	08	SE	5/14/71
11N/17E-4X2 (f)	NA	90	3600	3510	5/22/55	California DWR	11N	17E	04	NA	NA
11N/17E-5R2	98	67	3590	3523	9/1/81	Freiwald	11N	17E	05	SE	NA
11N/17E-5R3	175	70	3590	3520	9/1/81	Freiwald	11N	17E	05	SE	1959
11N/18E-9L1	62	57	3300	3243	8/2/78	Freiwald	11N	18E	09	SW	NA
12N/14E-24E1	124	23	5520	5497	8/13/81	Freiwald	12N	14E	24	NW	NA
12N/14E-36R1	10	9	5125	5116	8/18/81	Freiwald	12N	14E	36	SE	NA
12N/15E-2H1	14	>14	4880	<4866	8/21/81	Freiwald	12N	15E	02	NE	NA
12N/15E-3L1	30	9	5040	5031	8/29/81	Freiwald	12N	15E	03	SW	1857
12N/15E-3M1	147	29	5060	5031	8/21/81	Freiwald	12N	15E	03	SW	NA
12N/15E-7A1	NA	7	5270	5263	9/2/81	Freiwald	12N	15E	07	NE	NA
12N/15E-8D1	70	18	5250	5232	9/2/81	Freiwald	12N	15E	08	NW	NA
12N/15E-8D2	24	18	5250	5232	9/2/81	Freiwald	12N	15E	08	NW	NA
12N/15E-9M1	32	22	5180	5158	8/29/81	Freiwald	12N	15E	09	SW	NA
12N/15E-9Q1	46	25	5240	5215	8/29/81	Freiwald	12N	15E	09	SE	NA
12N/15E-11B1	40	12	5050	5038	8/21/81	Freiwald	12N	15E	11	NE	NA
12N/15E-11G1	10	7	5110	5103	8/21/81	Freiwald	12N	15E	11	NE	NA
12N/15E-17B1	13	5	5270	5265	9/2/81	Freiwald	12N	15E	17	NE	NA
12N/15E-17B2	75	6	5270	5264	9/2/81	Freiwald	12N	15E	17	NE	NA
12N/15E-17B3	14	9	5270	5261	9/2/81	Freiwald	12N	15E	17	NE	NA
12N/15E-17N1	60	11	5285	5274	8/19/81	Freiwald	12N	15E	17	SW	NA
12N/15E-19H2	21	10	5080	5070	9/2/81	Freiwald	12N	15E	19	NE	NA
12N/15E-20P1	46	22	5060	5038	8/19/81	Freiwald	12N	15E	20	SW	NA
12N/15E-20P2	190	43	5015	4972	8/19/81	Freiwald	12N	15E	20	SW	1966
12N/15E-29C1	42	37	4940	4903	8/19/81	Freiwald	12N	15E	29	SW	NA
12N/15E-31L1	29	13	5040	5027	8/18/81	Freiwald	12N	15E	31	SW	NA
12N/15E-31M1	22	12	5160	5148	11/22/17	Freiwald	12N	15E	31	SW	NA
12N/15E-33D1	540	290	4730	4440	8/19/81	Freiwald	12N	15E	33	NW	8/71
12N/16E-18L1	26	12	4590	4578	8/20/81	Freiwald	12N	16E	18	SW	NA
12N/16E-19C2	47	43	4610	4567	8/20/81	Freiwald	12N	16E	19	NW	1/27/59
12N/17E-4D1	700	521	3980	3459	9/1/81	Freiwald	12N	17E	04	NW	1937
12N/17E-4N1	17	11	3960	3949	8/31/81	Freiwald	12N	17E	04	SW	NA

TABLE B.1 - WELL INVENTORY

Well Identification	Total Depth (Ft)	Depth to Water (Ft)	Surface Elevation (Ft)	Elevation of static water level(g) (Ft)	Date Water Level Measured	Source	Location				Date Drilled
							Twp	Rng	Sec	Qtr	
12N/17E-4P1	NA	475	3960	**3485**	8/31/81	Freiwald	12N	17E	04	SW	NA
19(b)	550	500	4000(a)	3500	11/17	Thompson	12N	17E	08	SW	<1917
20	550	400	3880(a)	3480	11/17	Thompson	12N	17E	16	SW	<1917
12N/17E-17J1	750	431	3910	**3479**	5/7/64	Freiwald	12N	17E	17	SE	NA
12N/17E-18A1(b)	550	500	4040	**3540**	11/81	Freiwald	12N	17E	18	NE	NA
PS-2	580	430	3407(c)	**2977**	5/26/88	Mark Group	12N	18E	14	SW	6/21/87
PS-3	600	455	3440(c)	**2985**	6/87	Mark Group	12N	18E	15	NW	6/23/87
12N/18E-30E1	244	212	3760	**3548**	8/31/81	Freiwald	12N	18E	30	NW	NA
12N/18E-30E2	227	220	3760	**3540**	8/31/81	Freiwald	12N	18E	30	NW	NA
13N/15E-2P1	217	42	5440	**5398**	8/27/81	Freiwald	13N	15E	02	SW	NA
13N/15E-9G1	14	11	5680	**5669**	8/14/81	Freiwald	13N	15E	09	NE	NA
13N/15E-9H1	59	17	5620	**5603**	8/14/81	Freiwald	13N	15E	09	NE	NA
13N/15E-11F1	153	98	5410	**5312**	8/27/81	Freiwald	13N	15E	11	NW	NA
13N/15E-11G1	125	58	5440	**5382**	8/27/81	Freiwald	13N	15E	11	NE	NA
13N/15E-22D1	15	9	5440	**5431**	8/14/81	Freiwald	13N	15E	22	NW	NA
13N/15E-22J1	154	153	5250	**5097**	8/14/81	Freiwald	13N	15E	22	SE	NA
13N/15E-34K1	93	11	5000	**4989**	8/29/81	Freiwald	13N	15E	34	SE	NA
13N/15E-34M1	200	65	5080	**5015**	8/29/81	Freiwald	13N	15E	34	SW	1978
13N/15E-34N1	115	16	5060	**5044**	8/29/81	Freiwald	13N	15E	34	SW	1978
13N/15E-36A1	72	41	4890	**4849**	8/20/81	Freiwald	13N	15E	36	NE	NA
13N/15E-36A2	72	39	4890	**4851**	8/20/81	Freiwald	13N	15E	36	NE	NA
13N/15E-36N1	217	150	4780	**4630**	8/20/81	Freiwald	13N	15E	36	SW	NA
13N16E07B1	271	212	5510	**5298**	8/20/81	Freiwald	13N	16E	07	NE	NA
W-8	480	>480(d)	4400(a)	<3920(e)	8/87	Mark Group	13N	16E	12	SE	8/24/87
13N/17E-18N1	879	344	4349	**4005**	1/15/81	Freiwald	13N	17E	18	SW	1912
13N/17E-33X1	700	>500	3975	<3475	9/13/53	California DWR	13N	17E	33	NA	1937
14N/16E-14K2	121	31	4740	**4709**	8/26/81	Freiwald	14N	16E	14	SE	NA
14N/16E-14M1	457	92	4810	**4718**	8/26/81	Freiwald	14N	16E	14	SW	1/14/03
14N/16E-14P1	98	73	4760	**4687**	8/26/81	Freiwald	14N	16E	14	SW	NA
14N/16E-14Q1	133	119	4760	**4641**	8/26/81	Freiwald	14N	16E	14	SE	NA
14N/16E-22M1	15	12	4920	**4908**	8/25/81	Freiwald	14N	16E	22	SW	1900
14N/16E-22M2	84	16	4920	**4904**	8/25/81	Freiwald	14N	16E	22	SW	1954
14N/16E-28J1	27	26	5060	**5034**	8/25/81	Freiwald	14N	16E	28	SE	NA
W-7P	1000	474	4595	**4121**	10/17/81	Mark Group	14N	17E	09	SE	8/14/87
W-11P	1125	428	4548	**4120**	1/23/88	Mark Group	14N	17E	09	SE	12/3/87

TABLE B.1 - WELL INVENTORY

Well Identification	Total Depth (Ft)	Depth to Water (Ft)	Surface Elevation (Ft)	Elevation of static water level(g) (Ft)	Date Water Level Measured	Source	Location				Date Drilled
							Twp	Rng	Sec	Qtr	
14N/17E-14F1	725	266	4420	4154	8/28/81	Freiwald	14N	17E	14	NW	1937
W-5	1020	710(d)	4401	3691(e)	7/87	Mark Group	14N	17E	15	SE	7/28/87
W-12	1000	435(d)	4509	4074(e)	12/87	Mark Group	14N	17E	15	NW	12/11/87
W-14P	700	359	4472	**4113**	11/30/87	Mark Group	14N	17E	15	NW	10/30/87
W-15P	1000	338	4451	**4113**	3/10/88	Mark Group	14N	17E	15	SW	2/2/88
W-17	1000	500(d)	4479	3979(e)	2/88	Mark Group	14N	17E	15	NW	2/11/88
W-18P	720	330	4443	**4113**	5/4/88	Mark Group	14N	17E	15	NE	2/14/88
W-19P	1000	360	4463	**4103**	4/1/88	Mark Group	14N	17E	15	SW	2/3/88
W-24P	688	383	4488	**4105**	4/19/88	Mark Group	14N	17E	15	NW	4/5/88
W-4P	1000	390	4497	**4107**	9/3/87	Mark Group	14N	17E	16	NE	7/12/87
W-3P	734	483	4588	**4105**	8/13/87	Mark Group	14N	17E	17	NE	7/26/87
P-3	820	493	4600(a)	4107	3/6/87	Mifflin & Assoc.	14N	17E	17	NE	3/3/87
W-6	1000	630(d)	4549	3919(e)	7/87	Mark Group	14N	17E	18	SE	7/4/87
W-20	980	460(d)	4440	3980(e)	1/88	Mark Group	14N	17E	21	NE	1/27/88
L-1	775	453	4278	3825	2/21/87	Mifflin & Assoc.	14N	17E	23	SW	2/18/87
W-31P	897	345	4258	**3913**	2/22/88	Mark Group	14N	17E	25	NW	1/5/88
W-32	1040	380(d)	4248	3868(e)	1/88	Mark Group	14N	17E	25	NW	1/13/88
14N/17E-27A1	359	338	4280	3942	8/28/81	Freiwald	14N	17E	27	NE	NA
L-2	680	>680	4280(a)	<3600	2/25/87	Mifflin & Assoc.	14N	17E	33	NW	2/23/87
W-25P	1000	276	4200	**3924**	2/24/88	Mark Group	14N	18E	19	SW	12/22/87
W-26	640	280(d)	4168	3888(e)	1/88	Mark Group	14N	18E	30	NW	1/7/88
W-27	1000	320(d)	4138	3818(e)	2/88	Mark Group	14N	18E	30	NW	2/14/88
15N/17E-26Q1	190	110	4460	4350	7/31/58	Freiwald	15N	17E	26	SE	7/31/58

NA = Not available.
(a) Approximate value taken from topographic map.
(b) May be same well -- logs are identical.
(c) Values surveyed by Kennedy/Jenks/Chilton.
(d) Depth to water during drilling, these holes were abandoned prior to water level equilibration.
(e) Represents water level during drilling.
(f) Cannot locate within section.
(g) Bold print indicates higher confidence level in water level data.

TABLE B.2 - LITHOLOGIC LOG INVENTORY

ID	Relative Location	Source	Total Depth (Ft)	Surface Elevation (Ft)	Location				Date Drilled
					Twp	Rng	Sec	Qtr	
W-3P	West Well Field	Mark Group	734	4588	14N	17E	17	NE	7/26/87
W-4P	West Well Field	Mark Group	1000	4497	14N	17E	16	NE	7/12/87
W-5	West Well Field	Mark Group	1020	4401	14N	17E	15	SE	7/28/87
W-6	West Well Field	Mark Group	1000	4549	14N	17E	18	SE	7/4/87
W-7P	West Well Field	Mark Group	1000	4595	14N	17E	9	SE	8/14/87
W-8	Central Valley	Mark Group	480	4400(a)	13N	16E	12	SE	8/24/87
W-11P	West Well Field	Mark Group	1125	4548	14N	17E	9	SE	12/3/87
W-12	West Well Field	Mark Group	1000	4509	14N	17E	15	NW	12/11/87
W-14P	West Well Field	Mark Group	700	4472	14N	17E	15	NW	10/30/87
W-15P	West Well Field	Mark Group	1000	4451	14N	17E	15	SW	2/2/88
W-17	West Well Field	Mark Group	1000	4479	14N	17E	15	NW	2/11/88
W-18P	West Well Field	Mark Group	720	4443	14N	17E	15	NE	2/14/88
W-19P	West Well Field	Mark Group	1000	4463	14N	17E	15	SW	2/3/88
W-20	West Well Field	Mark Group	980	4440	14N	17E	21	NE	1/27/88
W-24P	West Well Field	Mark Group	688	4488	14N	17E	15	NW	4/5/88
W-25P	East Well Field	Mark Group	1000	4200	14N	18E	19	SW	12/22/87
W-26	East Well Field	Mark Group	640	4168	14N	18E	30	NW	1/7/88
W-27	East Well Field	Mark Group	1000	4138	14N	18E	30	NW	2/14/88
W-31P	East Well Field	Mark Group	897	4258	14N	17E	25	NW	1/5/88
W-32	East Well Field	Mark Group	1040	4248	14N	17E	25	NW	1/13/88
W-33	East Well Field	Mark Group	1000	4249	14N	17E	25	NW	3/5/88
W-35	East Well Field	Mark Group	1055	4279	14N	17E	24	SW	1/26/88
W-36	East Well Field	Mark Group	1010	4109	14N	18E	30	SW	2/23/88
PS-1	Upslope of Piute Spring	Mark Group	540	3420(a)	12N	18E	22	SW	6/13/87
PS-2	Upslope of Piute Spring	Mark Group	580	3407(c)	12N	18E	14	SW	6/21/87
PS-3	Upslope of Piute Spring	Mark Group	600	3440(c)	12N	18E	15	NW	6/23/87
L-1	Btwn E & W Well Fields	Mifflin & Assoc.	775	4278	14N	17E	23	SW	2/18/87
L-2	South of West Well Field	Mifflin & Assoc.	680	4280(a)	14N	17E	33	NW	2/23/87
P-3	West Well Field	Mifflin & Assoc.	730	4600(a)	14N	17E	17	NE	3/3/87
20	South of Lanfair Butte	Thompson	550	3880(a)	12N	17E	16	SW	<1917
19(b)	Southwest of Lanfair Butte	Thompson	550	4000(a)	12N	17E	8	SW	<1917
12N/17E-8X1(b)	Southwest of Lanfair Butte	California DWR	550	4000	12N	17E	8	SW	<1919
12N/17E-18A1(b)	Southwest of Lanfair Butte	Freiwald	550	4040	12N	17E	18	NE	NA

(a) approximate value taken from topographic map.

(b) These three logs are identical. May be same well although location and elevation is unclear. Freiwald reports section 18 and an elevation of 4040 while Thompson and California DWR report as being located in section 8 and California DWR reports an an elevation of 4000.

(c) Values estimated by Kennedy/Jenks/Chilton.

TABLE B.3 - INVENTORY OF SPRINGS

Location and Identification No.	Spring Name	Date Measured	Discharge (gal/min)	Surface Elevation (Ft)	Water Use	Improvements
11N/17E-4RS1	Vontrigger Spring	9/1/81	3.18 ft. to water	3550	Domestic	Concrete Basin with Pipe
12N/15E-1ES1	Rock Spring	8/21/81	2.00	4800	Stock	Concrete Basin
12N/15E-27BSI	Boulder Spring	8/19/81	0.23	4820	Stock	Trough with Pipe
12N/18E-24DSI	Piute Spring	5/26/88	45.10	2892(a)	Domestic and Stock	Pipe
13N/15E-9NSI	Bathtub Spring	8/14/81	0.04	5830	Stock	Trough
14N/16E-29MSI	Keystone Spring	8/25/81	0.02	5830	Stock	Trough with Pipe
14N/16E-30LSI	Keystone Mine Spring	8/25/81	2.00	6240	Unused	Boxed Basin
15/17E-16RSI	Indian Spring	8/26/81	1.00	5010	Stock	Trough with Pipe
15N/17E-22ASI	Maipais Spring No. 2	8/26/81	0.33	4680	Stock	Boxed Basin with Pipe
15N/17E-27HSI	Coates Spring	8/26/81	1.00	4640	Stock	Boxed Basin with Trough, Pipe, and Steel Tank

(a) Value estimated by Kennedy/Jenks/Chilton

APPENDIX C

WELL LOCATION IDENTIFICATION SYSTEM

APPENDIX C

WELL LOCATION IDENTIFICATION SYSTEM

Freiwald (1984) and California Department of Water Resources (1956) employ a similar well numbering convention based on Township, Range, and Section subdivisions. Each section is then subdivided into 16, 40-acre plots which are lettered "A" through "R" ("I" and "O" have been omitted to avoid confusion). When a well could not be accurately located to a 40-acre plot, the letter "X" is used for the location of the 40-acre plot. A sequential number following the letter designation for the 40-acre plot is used to differentiate between wells when more than one well is located within a 40-acre plot. Figure C.1 gives an example of the naming convention. Lanfair Valley is entirely in the northeast quadrant of San Bernardino base line and meridian. For purposes of this report where duplicate data occurred in the references, Freiwald (1984) has been identified as the source in the well inventory summary, since his report is more recent and also more detailed.

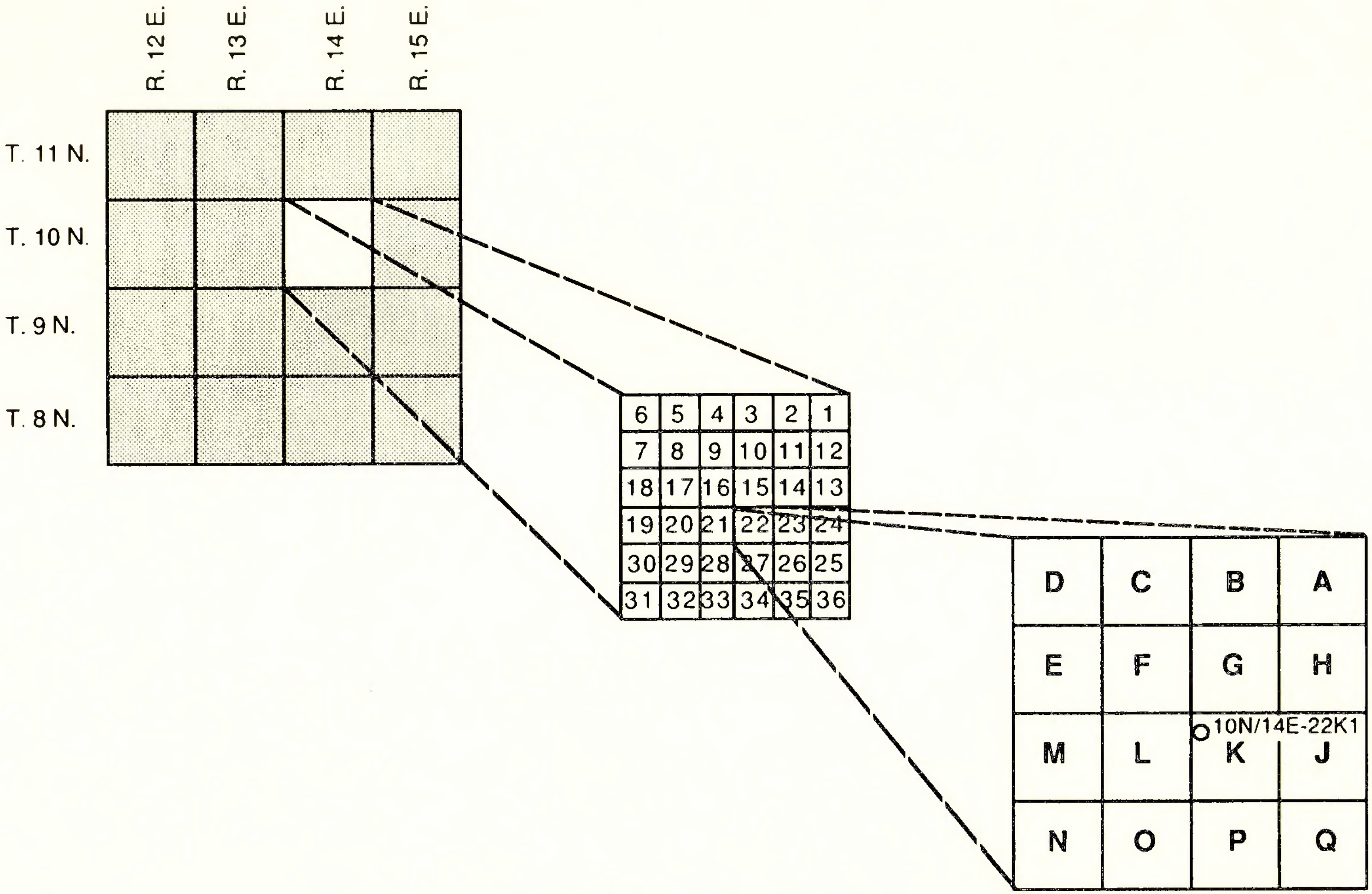

FIGURE C.1

WELL AND SPRING NUMBERING SYSTEM

CASTLE MOUNTAIN PROJECT

ENVIRONMENTAL SOLUTIONS, INC.

REVISED 8/16/88
ENVIRONMENTAL SOLUTIONS

APPENDIX D

WELL GROUND WATER CHEMISTRY SUMMARY

TABLE D.1 - GROUNDWATER CHEMISTRY SUMMARY

Local Identifier	Sample Date	Source	Total Dissolved Solids	Conductivity umhos	pH	Temperature Degrees C	Hardness (CaCO3) mg/l	Calcium (Ca) mg/l	Magnesium (Mg) mg/l	Sodium (Na) mg/l	Sodium Absorbtion Ratio
11N/15E-17M2	81-08-18	Freiwald	557.00	747.00	7.10	25.40	260.00	78.00	16.00	65.00	1.80
11N/16E-1PS1	81-08-28	Freiwald	172.00	- -	- -	- -	67.00	22.00	3.00	15.00	0.80
11N/17E-4RS1	81-9-01	Freiwald	307.00	390.00	7.10	26.10	110.00	35.00	5.60	33.00	1.40
	88-06-11	Mark Group	308.00	425.00	7.40	18.30	- -	34.60	5.80	33.40	- -
11N/17E-5R1	64-5-7	Freiwald	427.00	650.00	8.00	- -	191.00	32.00	27.00	73.00	2.30
11N/17E-5R3	67-05-19	Freiwald	- -	597.00	7.90	- -	190.00	63.00	8.00	46.00	1.50
12N/15E-1ES1	81-08-21	Freiwald	- -	508.00	7.60	21.60	- -	- -	- -	- -	- -
12N/15E-3L1	81-08-29	Freiwald	663.00	880.00	7.30	21.10	370.00	95.00	32.00	100.00	2.40
12N/15E-27BS1	81-08-19	Freiwald	228.00	320.00	7.10	35.00	100.00	28.00	7.80	31.00	1.40
12N/16E-19C1	64-05-26	Freiwald	- -	420.00	8.40	20.00	130.00	36.00	9.00	47.00	1.80
12N/16E-19C2	59-05-16	Freiwald	- -	673.00	7.90	- -	140.00	43.00	9.00	97.00	3.50
12N/16E-19D1	81-08-20	Freiwald	389.00	520.00	7.60	27.60	170.00	43.00	14.00	73.00	2.70
12N/17E-4D1	81-09-02	Freiwald	293.00	420.00	7.50	25.80	150.00	35.00	15.00	35.00	1.40
12N/17E-17J1	78-07-27	Freiwald	- -	340.00	- -	30.00	120.00	33.00	9.30	25.00	1.00
	88-06-13	Mark Group	314.00	425.00	7.50	26.70	- -	44.10	10.10	26.80	- -
12N/18E-24DS1	81-09-02	Freiwald	325.00	460.00	8.20	25.70	160.00	37.00	16.00	35.00	1.30
	88-06-11	Mark Group	306.00	425.00	7.40	27.20	- -	30.00	14.30	34.10	- -
	88-06-11	Mark Group	334.00	425.00	7.40	27.20	- -	32.30	14.40	33.10	- -
13N/15E-2P1	81-08-27	Freiwald	369.00	581.00	8.40	26.00	220.00	66.00	13.00	30.00	0.90
13N/15E-9NS1	81-08-14	Freiwald	- -	624.00	7.00	23.30	- -	- -	- -	- -	- -
13N/15E-36A1	81-08-20	Freiwald	482.00	735.00	7.50	21.30	290.00	79.00	23.00	52.00	1.40
13N/16E-7B1	81-08-20	Freiwald	244.00	396.00	7.30	16.60	170.00	52.00	8.80	14.00	0.50
	88-06-15	Mark Group	282.00	410.00	7.10	17.20	- -	60.80	9.80	14.30	- -
13N/17E-18N1	81-09-01	Freiwald	257.00	370.00	7.70	24.50	130.00	41.00	6.80	30.00	1.20
	88-06-15	Mark Group	282.00	400.00	7.20	25.60	- -	39.60	6.60	30.60	- -
14N/16E-14K1	81-08-26	Freiwald	- -	860.00	7.60	22.10	- -	- -	- -	- -	- -
14N/16E-14K3	52-06-27	Freiwald	- -	1,450	7.70	- -	550.00	119.00	61.00	123.00	2.30
14N/16E-14M1	81-08-26	Freiwald	1,920	2,990	7.30	23.40	1,200	270.00	130.00	150.00	1.90
14N/16E-15Q1	59-05-16	Freiwald	3,720	4,450	7.30	18.80	2,500	645.00	216.00	237.00	2.10
14N/16E-22M1	64-05-07	Freiwald	2,050	2,400	7.70	- -	1,057	295.00	78.00	227.00	3.00
14N/16E-22M2	81-08-25	Freiwald	- -	1,640	7.60	25.00	- -	- -	- -	- -	- -
14N/16E-29MS1	81-08-25	Freiwald	336.00	467.00	7.70	18.80	300.00	84.00	23.00	7.20	0.20
14N/17E-14F1	62-06-08	Freiwald	614.00	925.00	9.20	- -	103.00	20.00	13.00	164.00	7.00
14N/17E-15D1	88-06-15	Mark Group	318.00	450.00	7.10	23.30	- -	39.90	14.70	32.10	- -
	88-06-15	Mark Group	354.00	450.00	7.10	23.30	- -	39.70	14.80	34.50	- -
14N/17E-15M1	88-06-15	Mark Group	336.00	425.00	7.10	23.30	- -	41.20	15.50	22.90	- -
14N/17E-23L1	53-01-21	Freiwald	- -	833.00	8.30	- -	45.00	13.00	3.00	130.00	8.50
L-1	87-04-23	SRK	427.00	725.00	8.46	25.00	- -	3.60	0.22	160.00	- -
P-3	87-04-23	SRK		396.00	8.16	- -	- -	22.00	8.20	45.00	- -

SRK = Steffen, Robertson and Kirsten

(Note: this table may be expanded for the final report)

TABLE D.1 - GROUNDWATER CHEMISTRY SUMMARY

Local Identifier	Potassium (K) mg/l	Bicarbonate (HCO3) mg/l	Carbonate (CO3) mg/l	Alkalinity (as CaCO3) mg/l	Sulfate (SO4) mg/l	Chloride (Cl) mg/l	Fluoride (F) mg/l	Silica (SiO2) mg/l	Nitrate (NO3) mg/l	Nitrogen (as N) mg/l	Arsenic (As) ug/l	Boron (B) ug/l	Iron (Fe) ug/l
11N/15E-17M2	8.40	- -	- -	120.00	150.00	100.00	0.40	60.00	- -	1.60	2.00	140.00	100.00
11N/16E-1PS1	3.90	- -	- -	57.00	14.00	16.00	0.30	57.00	- -	1.50	3.00	60.00	10.00
11N/17E-4RS1	6.90	- -	- -	86.00	32.00	47.00	0.50	77.00	- -	4.10	9.00	140.00	<10
	7.70	99.00	<5	99.00	25.90	38.40	<0.5	- -	4.00	- -	7.00	- -	- -
11N/17E-5R1	7.60	147.00	0.00	121.00	54.00	120.00	0.40	40.00	4.50	- -	- -	160.00	- -
11N/17E-5R3	6.00	203.00	0.00	167.00	32.00	57.00	0.60	- -	17.00	- -	- -	140.00	- -
12N/15E-1ES1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/15E-3L1	1.90	- -	- -	480.00	27.00	62.00	1.70	54.00	- -	0.14	1.00	370.00	28.00
12N/15E-27BS1	1.50	- -	- -	140.00	9.00	16.00	0.60	47.00	- -	0.62	0.00	80.00	17.00
12N/16E-19C1	3.10	183.00	8.00	164.00	25.00	25.00	0.80	- -	1.20	- -	- -	160.00	- -
12N/16E-19C2	2.30	326.00	0.00	- -	39.00	32.00	8.60	- -	1.50	- -	- -	240.00	- -
12N/16E-19D1	2.60	- -	- -	230.00	42.00	30.00	1.50	40.00	- -	0.93	1.00	260.00	13.00
12N/17E-4D1	3.80	- -	- -	150.00	23.00	31.00	0.20	45.00	- -	3.40	4.00	150.00	33.00
12N/17E-17J1	6.50	- -	- -	- -	28.00	19.00	0.60	48.00	- -	1.00	- -	100.00	190.00
	7.50	144.00	<5	144.00	33.00	20.70	0.50	- -	1.00	- -	4.00	- -	- -
12N/18E-24DS1	6.40	- -	- -	190.00	26.00	21.00	0.20	67.00	- -	0.39	8.00	170.00	<10
	7.60	153.00	<5	153.00	17.70	16.90	0.50	- -	1.90	- -	7.00	- -	- -
	7.50	139.00	<5	139.00	18.80	16.90	0.50	- -	1.80	- -	8.00	- -	- -
13N/15E-2P1	1.40	- -	- -	110.00	140.00	26.00	1.40	24.00	- -	0.16	2.00	60.00	<10
13N/15E-9NS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
13N/15E-36A1	3.40	- -	- -	290.00	53.00	28.00	0.70	29.00	- -	8.90	0.00	230.00	36.00
13N/16E-7B1	1.40	- -	- -	140.00	46.00	10.00	0.80	24.00	- -	0.60	1.00	40.00	31.00
	1.20	149.00	<5	149.00	48.00	9.00	0.80	- -	0.48	- -	<2	- -	- -
13N/17E-18N1	2.30	- -	- -	140.00	27.00	22.00	0.20	39.00	- -	1.10	5.00	90.00	39.00
	2.30	149.00	<5	149.00	24.80	17.40	<0.5	- -	1.70	- -	2.00	- -	- -
14N/16E-14K1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-14K3	- -	232.00	- -	190.00	256.00	188.00	- -	- -	80.00	- -	- -	180.00	- -
14N/16E-14M1	7.60	- -	- -	140.00	780.00	460.00	0.80	28.00	- -	2.50	0.00	260.00	120.00
14N/16E-15Q1	18.00	207.00	0.00	170.00	1,940	542.00	0.80	22.00	4.80	- -	- -	200.00	- -
14N/16E-22M1	5.50	98.00	0.00	80.00	1,191	188.00	1.00	19.00	0.00	- -	- -	480.00	- -
14N/16E-22M2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-29MS1	0.70	- -	- -	300.00	<5	18.00	0.20	18.00	- -	0.06	3.00	50.00	93.00
14N/17E-14F1	4.40	162.00	15.00	158.00	149.00	99.00	0.60	23.00	0.00	- -	- -	570.00	- -
14N/17E-15D1	5.30	139.00	<5	139.00	24.40	38.00	<0.5	- -	2.30	- -	6.00	- -	- -
	5.10	139.00	<5	139.00	23.00	40.30	<0.5	- -	2.60	- -	6.00	- -	- -
14N/17E-15M1	5.10	134.00	<5	134.00	21.10	36.60	<0.5	- -	2.70	- -	3.00	- -	- -
14N/17E-23L1	- -	220.00	14.00	204.00	65.00	55.00	0.80	- -	3.00	- -	- -	360.00	- -
L-1	144.00	207.00	3.42	- -	81.00	68.00	1.50	- -	0.20	- -	<10	510.00	<50
P-3	3.70	129.00	<1	- -	36.00	30.00	- -	- -	- -	- -	<10	110.00	<50

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TABLE D.1 - GROUNDWATER CHEMISTRY SUMMARY

Local Identifier	Hydroxide (OH) mg/l	Silicon (Si) mg/l	Cadmium (Cd) mg/l	Chromium (Cr) mg/l	Copper (Cu) mg/l	Lead (Pb) mg/l	Manganese (Mn) mg/l	Mercury (Hg) ug/l	Molybdenum (Mo) mg/l	Selenium (Se) mg/l	Silver (Ag) mg/l	Zinc (Zn) mg/l	Barium (Ba) mg/l
11N/15E-17M2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
11N/16E-1PS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
11N/17E-4RS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	32.00	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
11N/17E-5R1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
11N/17E-5R3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/15E-1ES1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/15E-3L1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/15E-27BS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/16E-19C1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/16E-19C2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/16E-19D1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/17E-4D1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/17E-17J1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	25.40	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
12N/18E-24DS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	29.40	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	28.80	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
13N/15E-2P1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
13N/15E-9NS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
13N/15E-36A1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
13N/16E-7B1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	10.50	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
13N/17E-18N1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	17.40	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-14K1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-14K3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-14M1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-15Q1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-22M1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-22M2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/16E-29MS1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/17E-14F1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/17E-15D1	<5.0	24.40	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	<5.0	24.20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/17E-15M1	<5.0	22.60	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14N/17E-23L1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
L-1	<0.5	- -	<0.01	<0.01	0.01	<0.01	<0.01	<0.30	0.10	<0.01	<0.01	<0.01	<0.10
P-3	<0.5		<0.01	<0.01	0.01	<0.01	0.06	<0.30	<0.10	<0.01	<0.01	<0.01	<0.10

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